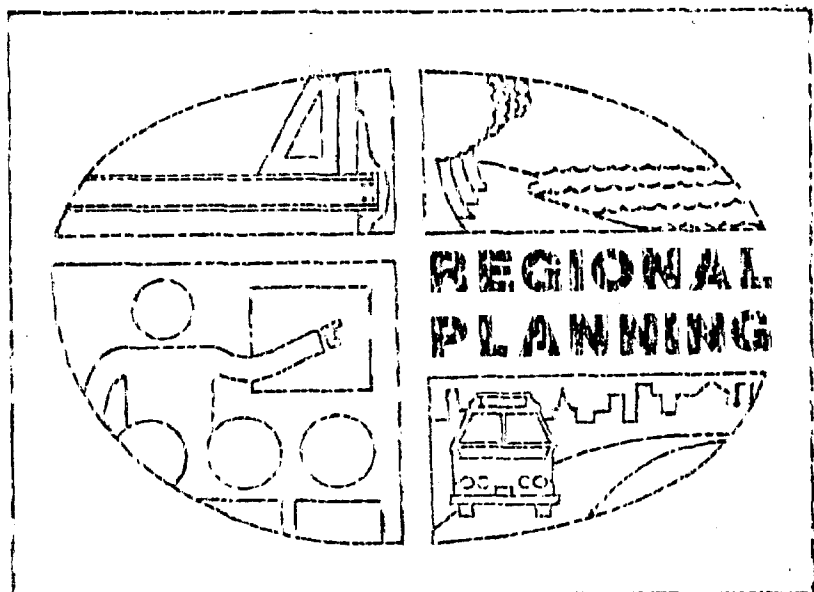


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Commission

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ASSESSMENT, IMPACT AND CONTROL
OF SHORELINE CHANGE
ALONG NEW HAMPSHIRE'S TIDAL SHORELINE

UPDATE

by
Rockingham Planning Commission

This report was financed in part by the Coastal Zone Management Act of 1972, administered by the Office of Coastal Zone Management, National Oceanic and Atmospheric Administration.

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ASSESSMENT AND IMPACT OF SHORELINE CHANGE

INTRODUCTION

This report is an update of the Strafford Rockingham Regional Council's 1978 report entitled "Assessment, Impact and Control of Shoreline Change Along New Hampshire's Tidal Shoreline". The purpose of the report is to identify specific locations which are experiencing shoreline change; to study the needs for harbor dredging, beach replenishment, storm protection structures and related measures; and develop desirable and cost-effective solutions.

The format of this revision is similar to that of the 1978 edition with most changes to be found in the sections on "General Coastal Processes" and "Control Alternatives in Areas Experiencing Significant Shoreline Change" (now called "Alternative Methods of Control in Areas Experiencing Significant Shoreline Change").

METHODOLOGY

Because this report is an update of the 1978 project, that piece remains the framework within which further research was conducted. The first step in updating the study was to formulate a comprehensive list of coastal construction projects undertaken since 1978 to determine which locations are continuing to undergo significant change. Sources of related erosion/deposition data were subsequently sought. The lack of recent detailed studies on the shoreline soon became apparent. The only regional (New Hampshire) studies undertaken since the early 1960's were the August 1977 Corps of Engineers report on erosion at North Beach, in Hampton, and Foss Beach, in Rye and the 1979 assessment of damages resulting from the Blizzard of '78. The Corps of Engineers has not made a survey of the entire coastline since 1959.

Following a review of the limited new data two areas were deleted as those experiencing significant change and three were added. Although removing a source of beach material, the stabilization of Great Boars Head, by construction of riprap, has slowed the rate of erosion there satisfactorily. Route 1A where it abutts the Ocean was removed with the intention of identifying specific problem areas. The three areas of significant change that were added are salt-marshes which are suffering symptoms of degradation: Bass Beach Saltmarsh, Little River Saltmarsh, and Parson's Creek Saltmarsh.

Once the eleven areas were identified, (See Map 1) the most recent data was utilized to describe existing conditions. Following this, an engineering consultant's service was procured to recommend mitigation measures -- with cost estimates -- for each of the 11 locations.

ASSESSMENT AND IMPACT OF SHORELINE CHANGE

MAJOR FINDINGS

*Areas of significant and potentially critical erosion (See Maps 1,2,3, and 4): dunes at north end of Seabrook Beach and 53 acres of dunes in the south-east corner of the town; north end of Hampton Beach; North Beach, Hampton; Straws Point, Rye; Varrel's Point, Rye; Rye Harbor; and Foss Beach, Rye.

*Areas of significant and potentially critical accretion: Hampton Harbor and Inlet, Little River Saltmarsh, Bass Beach Saltmarsh, Parson's Creek Saltmarsh.

Areas of dynamic activities (i.e. high tidal currents, but little net change): lower end, Piscataqua River; Dover Point; Fox Point; and Furber Strait.

**Areas where stabilization measures are failing: Straws Point, Rye -- piece meal riprap is ineffective; south shore, Ragged Neck, Rye -- piece meal riprap is ineffective.

**Areas where stabilization measures are working: Hampton inlet; Hampton Beach; Great Boars Head, Hampton; North Beach, Hampton; Varrel's Point, Rye; Foss Beach, Rye.

Areas where stabilization measures are causing unintended impact:

Hampton Inlet Jetties - interrupt longshore transport and cause shoaling in inlet and harbor

Hampton Beach Seawall - interrupts natural recession; reflects waves and causes beach erosion

Great Boars Head riprap - keeps headland from supplying sediment to beaches

North Beach Bulkhead and Seawall - interrupts natural recession; reflects waves and causes beach erosion

Rye Harbor Inlet - configuration allows unimpeded access to southshore of Ragged Neck by southeast waves and causes erosion

Foss Beach - continued rebuilding of shingle ridge interrupts natural recession

* Although some of these areas are now stabilized, they were experiencing continual erosion prior to stabilization.

**The present success of stabilization devices is of a short term nature. All stabilization devices fail over the long run.

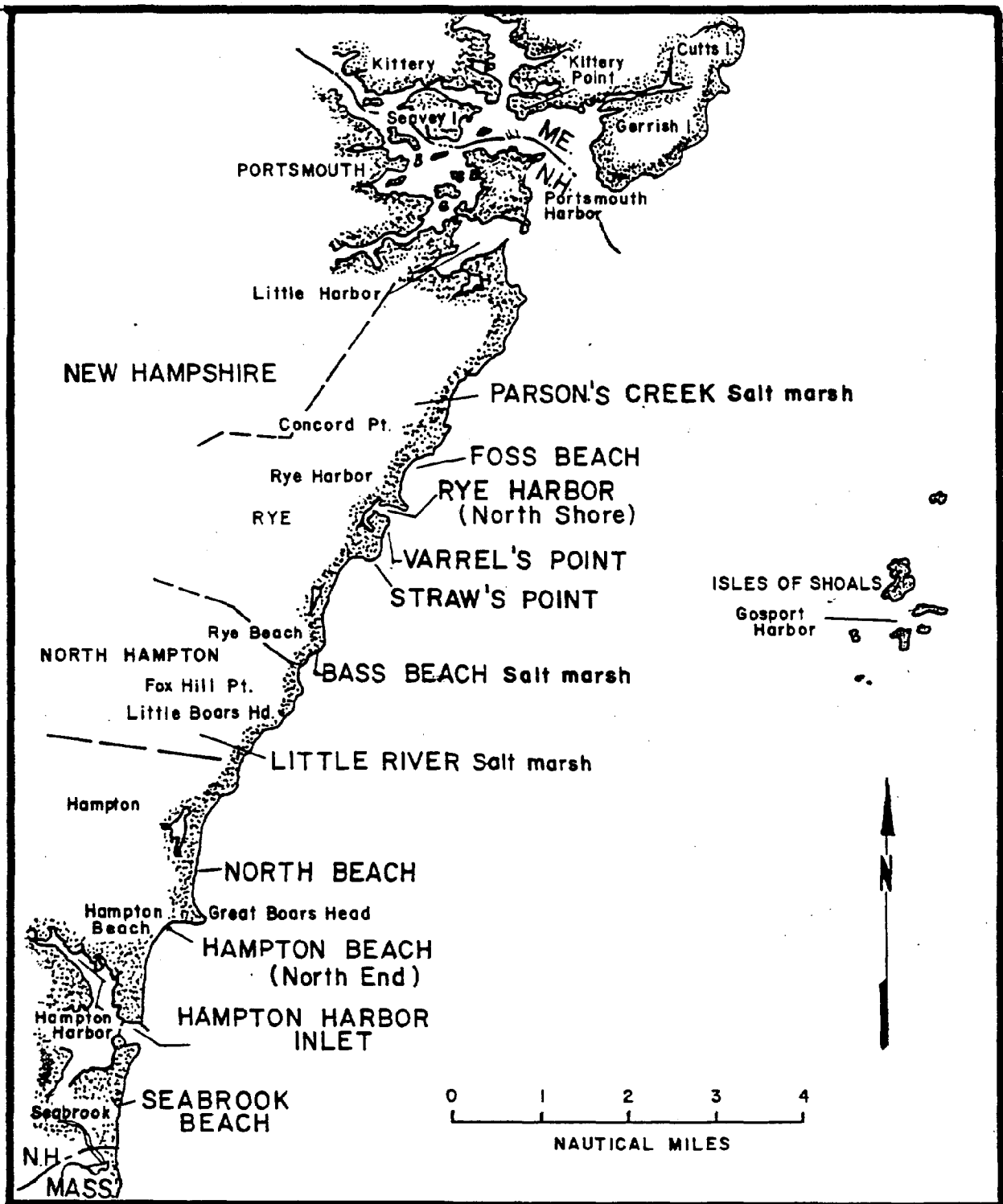
Significant data pertaining to agents of erosion and accretion in New Hampshire:

Longshore transport south of Great Boars Head - is continuous in a southerly direction

Longshore transport north of Great Boars Head - does not move material around the headlands. Predominant flow is from headlands to enclosed coves.

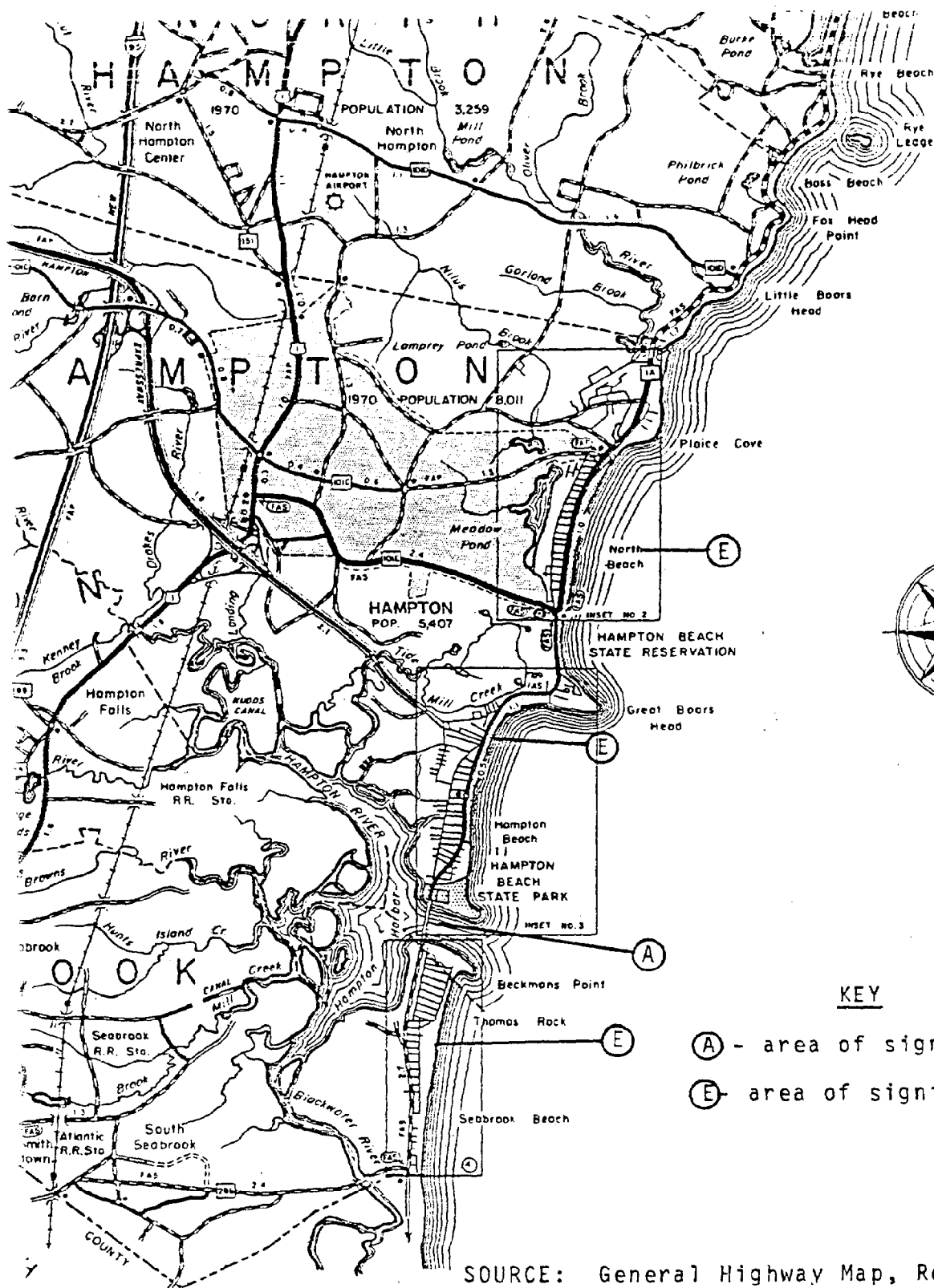
Source of beach material - is erosion of unconsolidated glacial deposits
Major agent of erosion - is the northeast storm, or low pressure systems with prevailing gale force winds from the northeast

Storm surge - increase the potential for damage of any northeast storm
Analysis of Corps of Engineers shoreline change data leads to the conclusion that erosion and accretion are cyclical events on New Hampshire's shoreline.



MAP 1

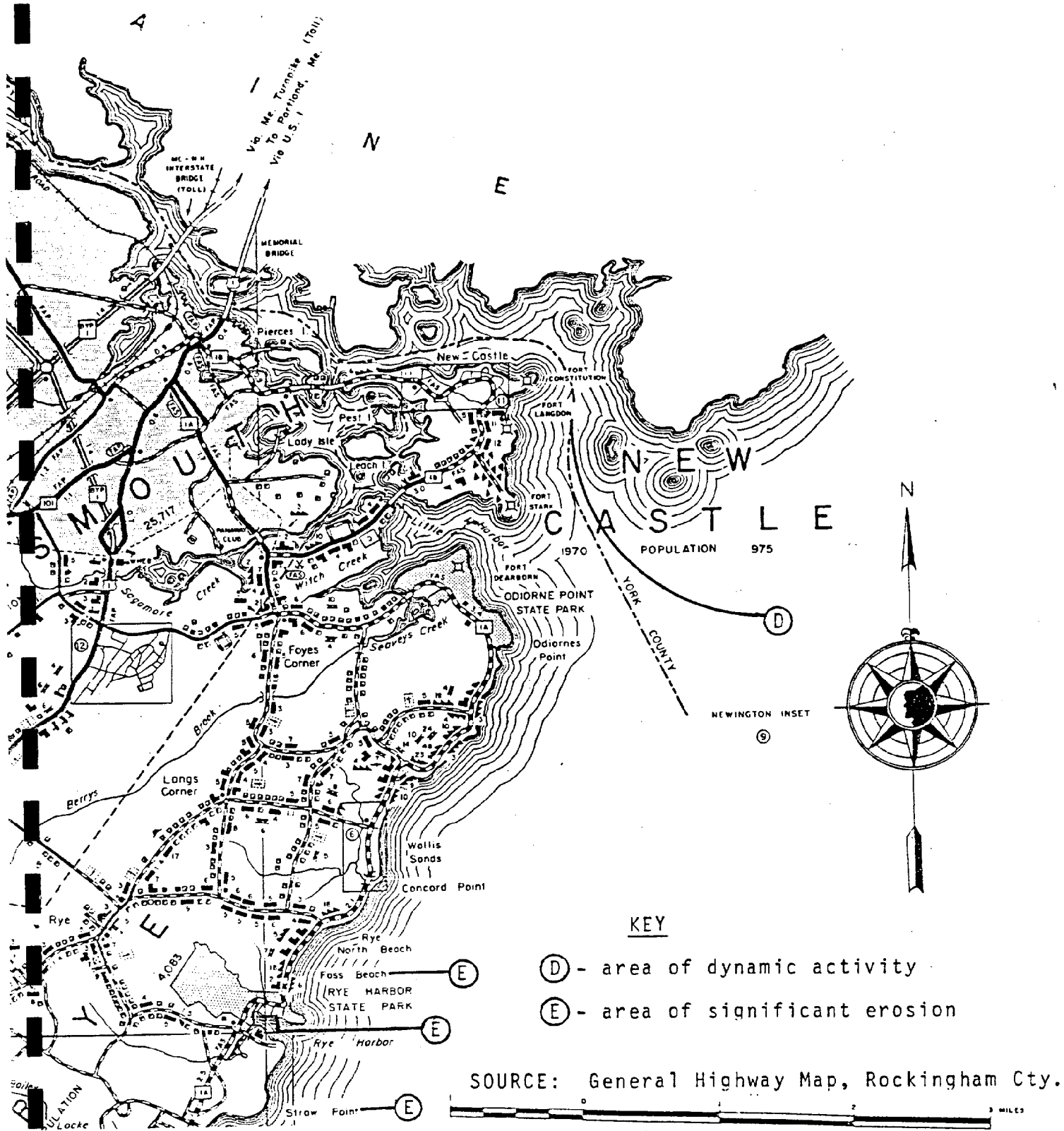
Areas Identified as those Experiencing Significant
Shoreline Change

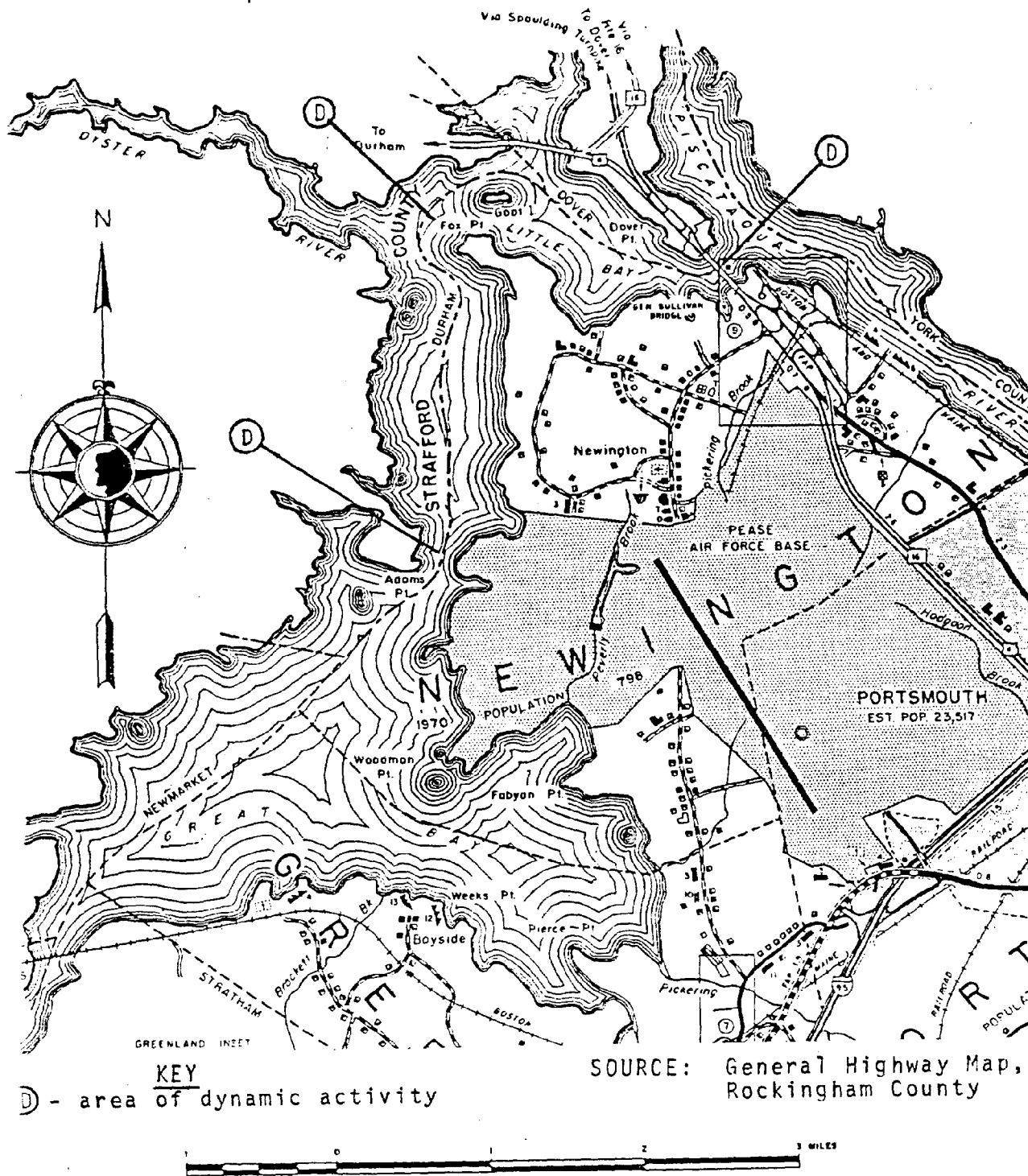


SOURCE: General Highway Map, Rockingham Cty.

BASE MAP (Seabrook Beach - Jenness Beach)

MAP 2





GLACIAL HISTORY

Introduction

The glacial history of the seacoast region of New Hampshire has influenced both the shape and composition of the shoreline. Glacial material deposited during the Wisconsin Stage of Pleistocene glaciation is the major constituent of beach material along the coast. Isostatic and eustatic sea level changes have affected the relative position of land and sea, and hence have controlled to a large degree the position of the shoreline. Also, although the present geologic age is an interglacial period, continental glaciation still influences the rise of sea level.

Glacial Deposits

During its existence, the continental glacier deposited much material which it had eroded previously from the north. Material was deposited either during the advance or retreat of the glacier. During the advance, till was deposited in a thin veneer over most of New England. At its terminal and other recessional points where conditions were such to maintain an equilibrium between ice movement and melting, the glacier deposited till as moraines parallel to the terminus of the glacier. Moraines occurred only when the environmental conditions were stable enough to allow continuous deposition in one place. In New Hampshire there are none of importance above sea level.

As the ice melted and the glacier retreated the material held within the glacier was dropped in place and redistributed by the water liberated by the melting. Most of this material was borne towards the sea and deposited as an outwash plain. This plain was of gradual, uniform slope, broken here and there by pre-existing irregularities in the topography composed of both bedrock and till.

These outwash plains extended well offshore of the present New Hampshire shoreline. When the outwash was deposited, most of the continental shelf was exposed and the outwash extended from the edge of the wasting glacier to the sea. This outwash plain provided much of the material which has been reworked by the sea as sea level rose towards its present position and provided material for beaches along New Hampshire coastlines.

Changes in Sea Level

Continental glaciation's most notable impact on New Hampshire's coastline was a result of the changes in sea level which glaciation incurred. These changes were caused both by the trapping of precipitation as glacial ice and the depression of the crust by the weight of the glacial ice.

Precipitation fell as snow on the growing glaciers. Accordingly, the sea level dropped because this precipitation did not flow back to the sea (see Figure 1). Measurements show that during the most recent stage of glaciation the sea level fell 325 feet (Flint, 1971).

When the glacier was at its maximum position, the sea level occupied its lowest level. At this point, the coastal processes which occur along the New Hampshire shoreline today were also active. These processes reworked the coastal plain sediments into beach deposits. Barrier bars, dunes, saltmarshes, estuaries all formed as the sea occupied its lowest position. These features slowly moved inland as the sea level rose (see Figure 2). Melting glacial ice fed the sea which rose at a rate of 80 cm. per 100 years soon after melting began.

As melting continued, the rate of sea level rise decreased. Three thousand to five thousand years before present (B.P.) the present sea level was reached. Since that time sea level has risen, but at a minimal rate. During the period from 6300 to 3375 years B.P., the sea level rose at a rate of 21 cm. per 100 years, as compared to the pre-existing rate of 80 cm. per 100 years. For the past 3000 years, the rate has slowed even further to 3.5 cm. per 100 years (McIntire and Morgan, 1964).

Crustal depression as a result of the weight of the ice occurred in New Hampshire. Depression depended on the amount of overlying ice and hence decreased with distance from the core of the glacier. The relationship between ice thickness and crustal depression was roughly three to one (Flint, 1971). Here in New Hampshire, depression has been estimated at 40 feet (McIntire and Morgan, 1964). Today, rebound of the crust is complete (see Figure 3).

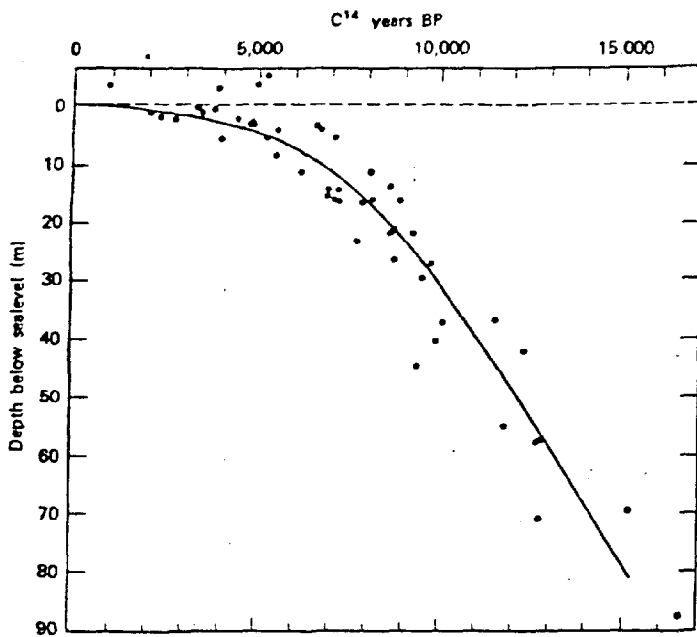


Figure 12-3. Submergence curve based on nearly 50 C^{14} -dated samples of oysters taken from growth positions judged to have been close to sealevel. Samples are from various depths along or off several coasts thought to have been relatively stable. C^{14} ages are plotted against depths. Curve reflects progressive submergence, believed to be chiefly eustatic. Compare a similar curve for the Netherlands constructed by Jelgersma (in Sawyer, ed., 1966, p. 62) and the curve in Milliman and Emery, 1968, fig. 1; also fig 12-2. (After Shepard, 1963b, p. 1, 2.)

SOURCE: Flint, 1971

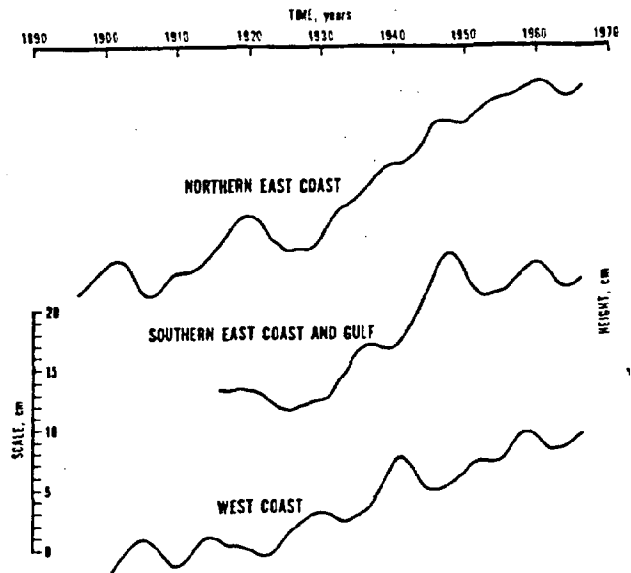


Fig. 10. Averaged damped series classifying United States sea level characteristics into Northern East Coast Area (north of Cape Hatteras), Southern East Coast and Gulf Area (south of Cape Hatteras), and West Coast Area.

SOURCE: Hicks, 1972

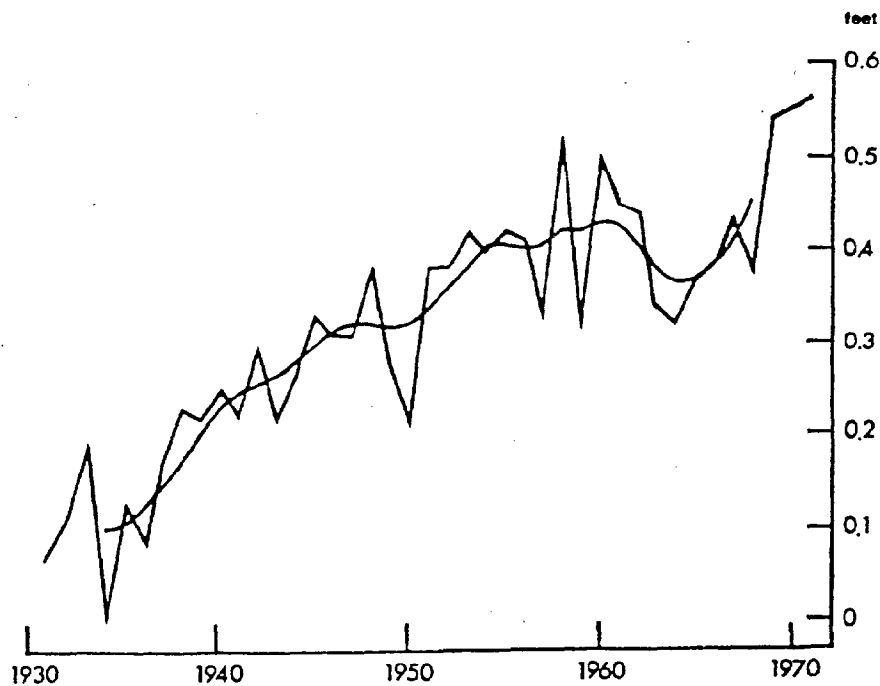


Figure 13: Yearly mean sea level at Newport, Rhode Island.

FIGURE 1

SOURCE: NERBC, 1976

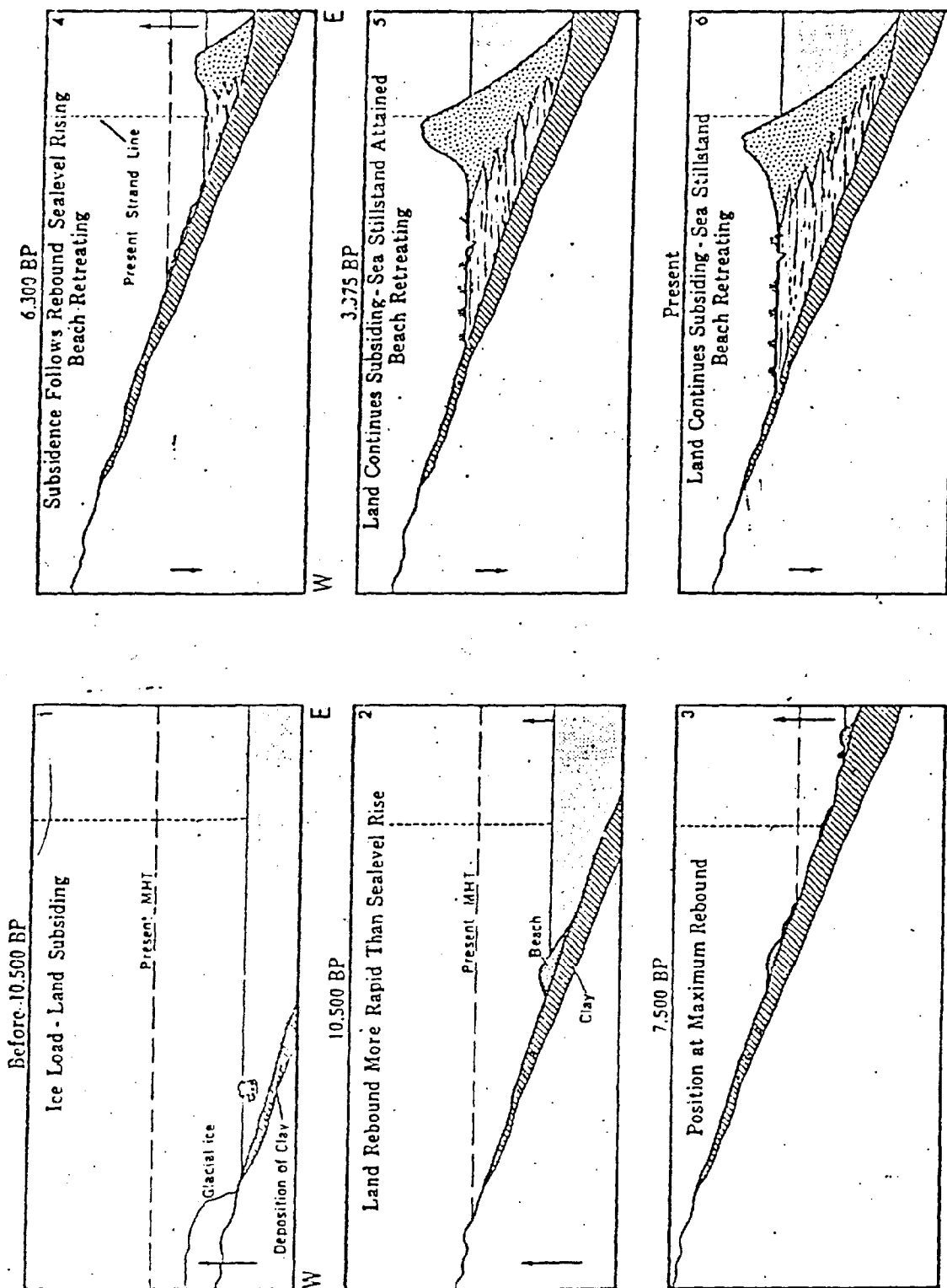


Fig. 10. Plum Island strandline changes and beach development is correlated with relative changes of level for the past 11,000 years. Direction of strandline displacement is shown by the position of the vertical dashed line.

SOURCE: McIntire and Morgan, 1964

FIGURE 2

The Present Shoreline

The shoreline at present is influenced by the same two factors which have governed its position for the past 15,000 years. These factors are the rise of sea level and the rebound of the crust following the unloading of glacial ice. However, the influence has abated recently and the present shoreline has remained relatively stable, although the transgression of the sea is clearly still in progress, though at a reduced rate.

An important fact to note about the present period following Wisconsin glaciation is that it is an interglacial period with all evidence pointing towards the onset of another continental ice sheet at some point in the future. This is important for several reasons.

First, glaciation has occurred throughout geologic time. The only record which remains of ancient glaciations are those deposits which have been indurated into resistant sedimentary and metamorphic rocks. All other evidence has been eroded away by sub-aerial erosion or subsequent glaciation. This situation emphasizes the transitory state of the present shoreline with respect to geologic time, despite its relative permanence to the human observer.

Second, from beach features of up to 50 meters above present sea level in Virginia and Georgia, scientists have deduced that previous interglacial sea levels were much higher than the present sea level (Flint, 1971). In fact, an interglacial shoreline in evidence west of Cape Lookout, North Carolina is 85 kilometers west of the present shoreline. Because the earth is a closed system and no water can be gained or lost, the same amount of water is present on the face of the earth now as was present there in times past (see Figure 3).

All this evidence points to the conclusion that the present sea level is ephemeral. Over the full term of the present interglacial period, sea level can be expected to rise substantially as a result of continued melting of the polar ice caps and the glaciers remaining in lower latitudes.

Mention of the glacial history of the area should help place in better context the present changes occurring along the New Hampshire coast. While the short term erosional and accretional cycles may show drastic gain or loss of land to the sea, over the long run in this interglacial period, rise of sea level and recession of the shoreline will occur. Despite the fact that continental

glaciation occurred thousands of years ago, the region continues to feel the effects of the Wisconsin glacier.

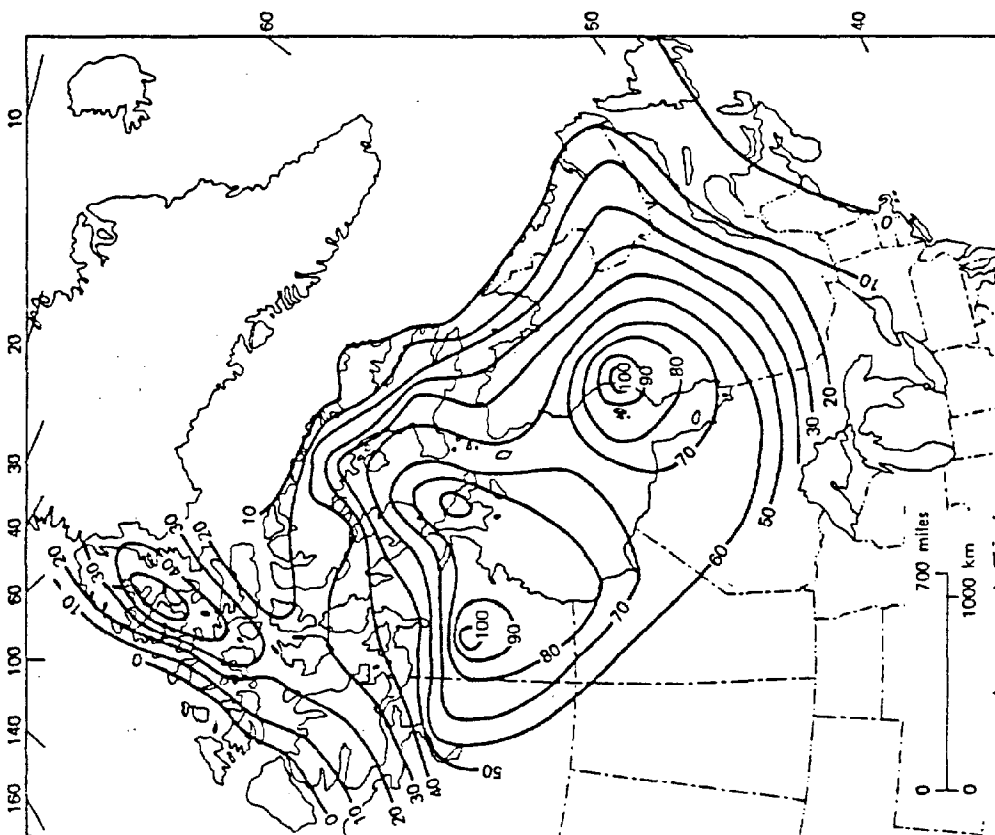


Figure 13-13 Isobases, plotted by a technique described by Andrews (1968b), from occurrences of postglacial marine sediments at 58 points in eastern and northern Canada where date and altitude of each occurrence are known. The curves are based on the sealevel of ~6000 BP, believed to be ~13m below that of today (Shepard, 1963b, fig 1). They show amplitude of emergence in meters $\pm 5m$, since that date. Three centers of uplift are evident, possibly reflecting the positions of comparatively thick residual ice bodies shortly before the date mentioned. (J. T. Andrews, unpublished.)

Flint, 1971

SOURCE:

FIGURE 3

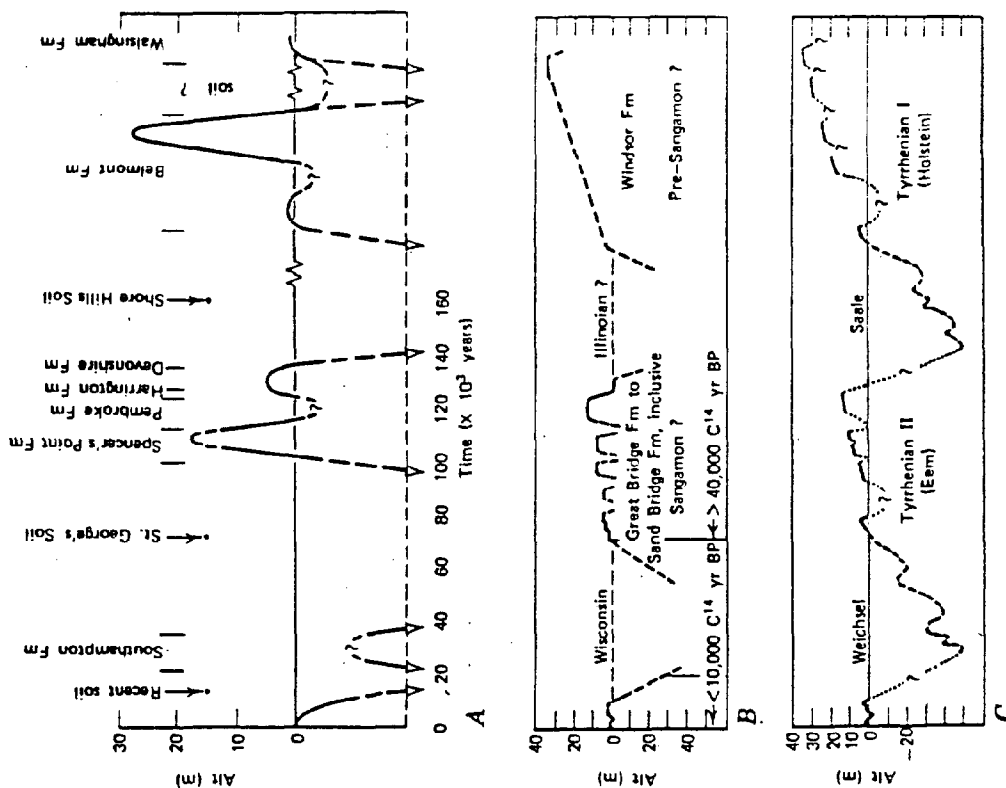


Figure 12-9 Generalized curves showing inferred fluctuations of relative sea level through time in three areas. A. Bermuda (After Land et al., 1967, p. 1002). Time calibration, based in large part on U-series dates, is by those authors. B. Norfolk district, Virginia (Oaks, 1965, with unpublished changes). C. Southern Mallorca (After Butzer and Cuerda, 1962, p. 414). Correlations are by those authors.

Flint, 1971

SOURCE:

FACTORS IN SHORE DEVELOPMENT

As sea and land interact, many factors influence the beach. Moving air and water carry material along the coast, eroding and depositing, constantly changing the shoreline.

The quality of the shore materials regulates the speed with which the beach areas undergo change. In much the same manner, the variance in the energy of the sea also controls change along the shoreline. In this section, these variables will be investigated and their importance noted with respect to the overall changes undergone along the coast.

Shore Materials

Along the New Hampshire shore, bedrock lies very near, if not at the surface of the land. Most of the bedrock along the tidal shoreline is highly metamorphosed sedimentary rock, varying from slate to schist. While the actual type of rock is relatively unimportant, its metamorphic history is of major importance. The bedrock of the seacoast region has undergone changes in crystalline structure and chemical composition as a result of the intense temperatures and pressures associated with regional metamorphism. These changes tended to make the bedrock more resistant to erosion and the attack of the sea than it was previously.

Material deposited by the continental glacier mantles most of New Hampshire's seacoast region. Most of this material is called till, and it varies in size and is unconsolidated. The unconsolidated glacial deposits are readily reworked by waves and transported in the direction of the long shore current.

As sea level approached its present level, major erosion of the glacial deposits occurred. The mantle on the pre-existing bedrock hills was quickly eroded by the wave attack of the sea. The glacial material on the seaward side of these bedrock hills has been almost completely removed and redistributed along adjacent beaches. Therefore, much of the supply of material to the adjacent beaches has been stopped, causing erosion problems.

In contrast, glacial deposits, with no core of bedrock, experience continual erosion unless protective devices are constructed around their bases. These

devices have the same effect as bedrock by limiting the amount of sediment liberated by the attack of the sea.

The supply of beach materials, then, has been interrupted by the slowing of sea level rise and the protection of the unconsolidated glacial headlands. The rise of sea level was responsible for stripping unconsolidated glacial deposits, not only from present headlands, but also from those which now lie offshore. At the time that the sea was attacking these deposits, the sea was also rising much more rapidly than at present. Therefore, the bedrock mounted very little resistance to erosion as the sea level rose and finally overtopped the headlands, while also stripping them of their glacial mantle. At present, the increasing stability of the land -- sea interface has limited the amount of new material which can be liberated by wave attack and distributed along adjacent beaches.

Longshore Transport

The longshore transport which is accomplished by longshore currents is the primary agent of locomotion of beach materials along the shore of New Hampshire. These currents are caused by several factors which have influenced the current directions along the shore since the sea began its interaction with the land in ancient geological time.

Wave motion, particularly that of breaking waves, is the most important active agent in beach building and erosion. As the waves break, run up the shore, and return, they carry sedimentary material onshore and offshore. Most waves arrive at an angle to the shore and set up a longshore current, moving sediments in a series of zig zags as successive wave fronts advance and retreat. The predominant direction of longshore transport is referred to as "downdrift" (See Figure 4).

Parts of the shore that extend into the water are more vigorously attacked than the shoreline inlets and bays. Incoming waves tend to bend, or are "refracted" around these peninsulas, headlands, extended beaches, and concentrate their energy on the front and sides of these areas (See Figure 5). Consequently, a current is established toward the beaches from the headland. This flow, of course, depends on the approach of the incoming waves. Wave approach from the north results in a net transport of beach material to the south end of the beach;

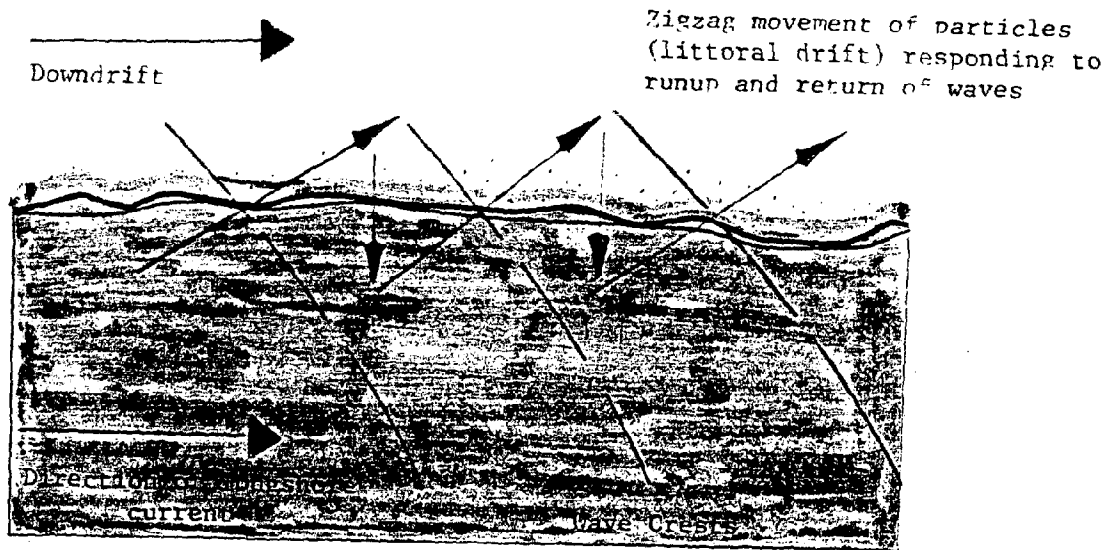


FIGURE 4 -- Longshore Transport of Sediments

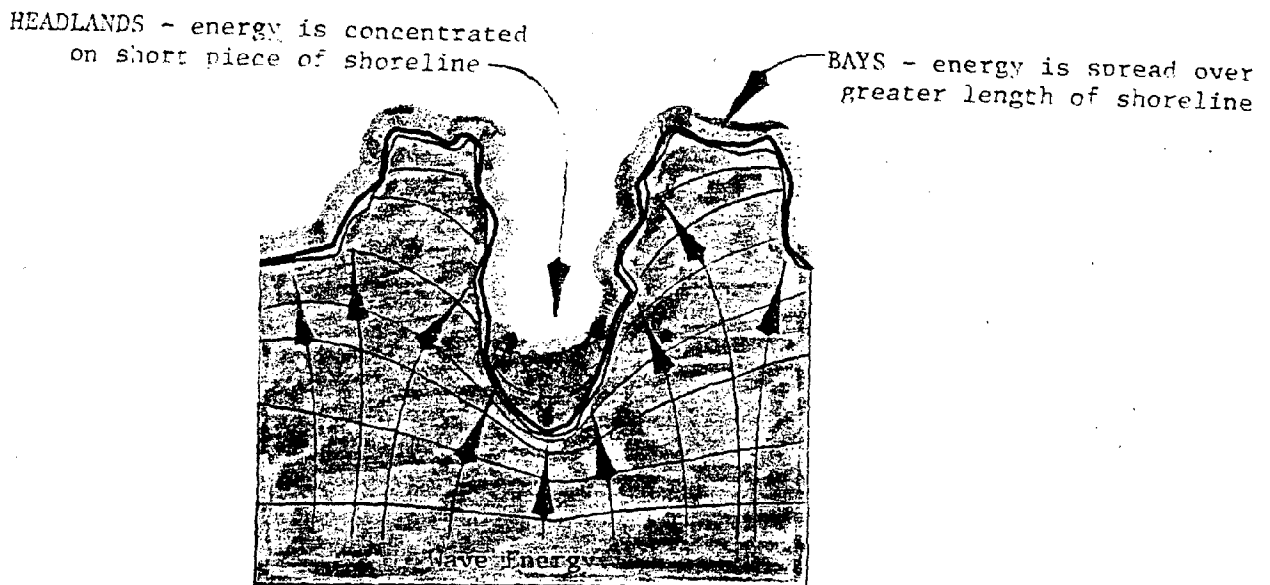


FIGURE 5 - Concentration of Wave Energy Around Headlands

southerly waves produce transport to the north. The dominant direction of transport is, however, from headlands toward beaches.

The sea attacks and erodes headlands and deposits the material in the pockets -- coves and beaches -- between headlands. The end toward which the system is striving is an equilibrium where there are no headlands or coves, just a straight linear beach. Of course, there are too many variables present for this equilibrium position ever to be reached. Yet, interference with the processes does upset the natural pursuit of this equilibrium and often creates more problems than solutions.

Other factors complicate the pattern of longshore transport. A pavement of boulders left by the complete erosion of a pre-existing glacial deposit is a good example. As waves carry off the lighter material, they drop the boulders in place. These boulders are large enough, in size and extent, to act as a small headland and set up counteracting longshore currents.

The ability of water to move material depends on its speed and force. Large waves or fast-moving currents can carry larger quantities and heavier sediments. Material picked up from inland heights, from river beds and banks, and from shoreline areas is deposited wherever the water is slowed down, and may be picked up again when the velocity of the water increases. When material is deposited, accretion occurs: growing shores are fed, or "nourished", by material that has been eroded from somewhere else. Erosion and accretion are two phases of the same process which may either occur at extremely slow rates or make dramatic changes in the shoreline within a human lifetime.

Storms

The major agent of erosion along the New Hampshire coast is the northeast storm, so called for its gale force northeasterly winds. From 1870 to 1945, storms have been recorded by the U.S. Weather Bureau (see Figures 6, 7, and 8). These records show that 50 percent of the storms were northeast storms (Corps of Engineers, 1962). These winds generate large, steep storm waves which can cause major erosion if certain conditions are in effect. One such condition is the intensity of the given storm.

The intensity of a storm can be measured by various methods. The usual measure is the barometric pressure at the center of the storm. The lower the pressure

falls, the more intense the storm. As a rule, the most intense storms create the strongest winds, and therefore larger, more intense waves.

Wave size is determined in part by the distance over which the wind influences the waves. This distance is called the fetch and varies by compass point for the New Hampshire shore. To the northeast, the fetch is 250 miles, extending to Nova Scotia. To the east and southeast, the fetch is unlimited, stretching to Europe. To the south, protection is derived from Cape Ann, Massachusetts which lies 20 miles away (Corps of Engineers, 1977).

The speed at which a storm travels regulates the effect of the storm on the coastline. A slow storm releases its energy over a greater duration of time than a fast storm, hence magnifying the storm's impact on the erosional cycle (Hayes and Boothroyd, 1969). If a storm is at its peak over two tidal cycles, it causes far greater erosion than a fast storm. During the first high tide, the beach does not lose much material to storm waves, the waves expending their energy on the beach face and smoothing the beach out. However, during the next high tide, the energy is released in a different manner. The beach face, smoothed by the previous high tide attack, gives no resistance to the waves and a massive amount of sand is removed from the beach face.

The phase of the moon is also important because it controls the level to which the high tide rises. Spring tides bring higher water levels which facilitate storm related erosion. In contrast, neap high tides dampen the effect of storm waves because of their lower level (Hayes and Boothroyd, 1969).

TIDES EXCEEDING MEAN HEIGHT AT PORTSMOUTH NAVY YARD, MAINE

<u>Feet in Excess of M. H. W.</u>	<u>No. Occurrences</u>	<u>Feet in Excess of M.H.W.</u>	<u>No. Occurrences</u>
2.0	52	3.0	2
2.1	42	3.1	1
2.2	40	3.2	1
2.3	18	3.3	2
2.4	18	3.4	0
2.5	14	3.5	1
2.6	10	3.6	1
2.7	3	3.7	0
2.8	2	3.8	0
2.9	5	3.9	1

TIDAL RANGES

<u>Location</u>	<u>Mean Range (Feet)</u>	<u>Spring Range (Feet)</u>
Merrimack River Entrance	8.3	9.5
Hampton Harbor	8.3	9.6
Gosport Harbor, Isle of Shoals	8.5	9.8
Jaffrey Point	8.7	10.0
Fort Point	8.6	9.9

Maximum Currents

<u>Location</u>	<u>Flood</u>	<u>Ebb</u>	
	<u>Direction (True)</u>	<u>Average Velocity</u>	<u>Direction (True)</u> <u>Average Velocity</u>
	<u>Degrees</u>	<u>Knots</u>	<u>Degrees</u> <u>Knots</u>
Gunboat Shoal	340	0.5	160 0.5
Isles of Shoals Light	20	0.3	200 0.3

Storms (1870 - 1945, inclusive)

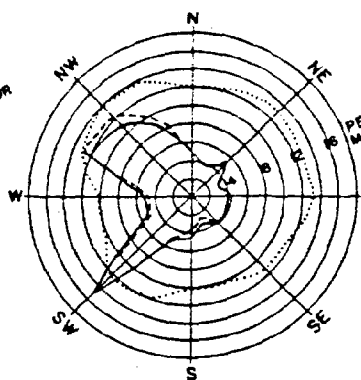
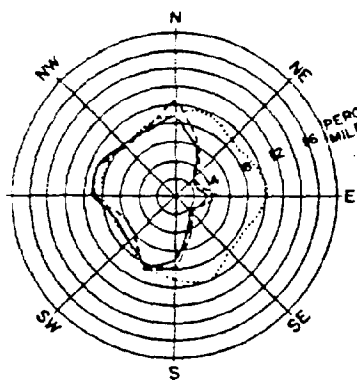
<u>Direction</u>	<u>N</u>	<u>NE</u>	<u>E</u>	<u>SE</u>	<u>S</u>	<u>SW</u>	<u>W</u>	<u>NW</u>	<u>Total</u>
No. of storms	3	80	9	14	12	15	13	14	160
Percent of total	2	50	6	9	7	9	8	9	100

SOURCE: Corps of Engineers, 1962

FIGURE 6

PORTLAND AIRPORT, MAINE

BOSTON AIRPORT, MASS.



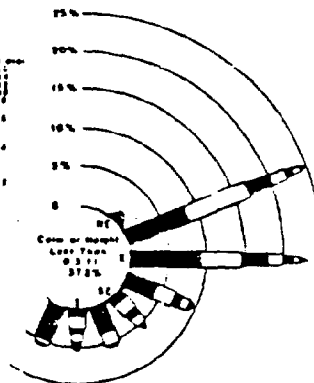
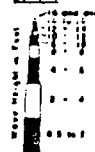
— % DURATION
 - - - % MOVEMENT
 ····· AV. SPEED (M.P.H.)

OCTOBER 1949 - SEPTEMBER 1952, INCLUSIVE

BASED ON HOURLY DURATION OF WIND SPEED AND DIRECTION OBSERVED BY U.S. WEATHER BUREAU

WIND DIAGRAMS

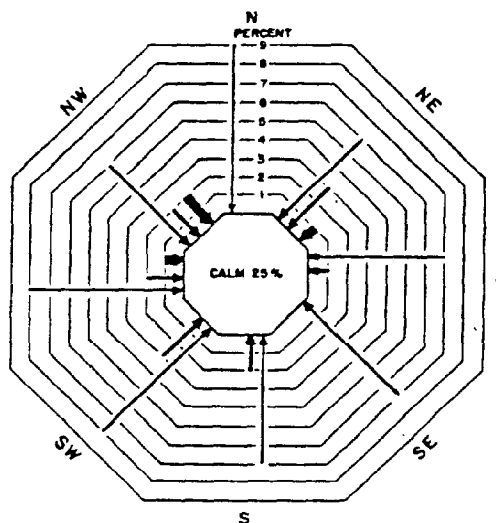
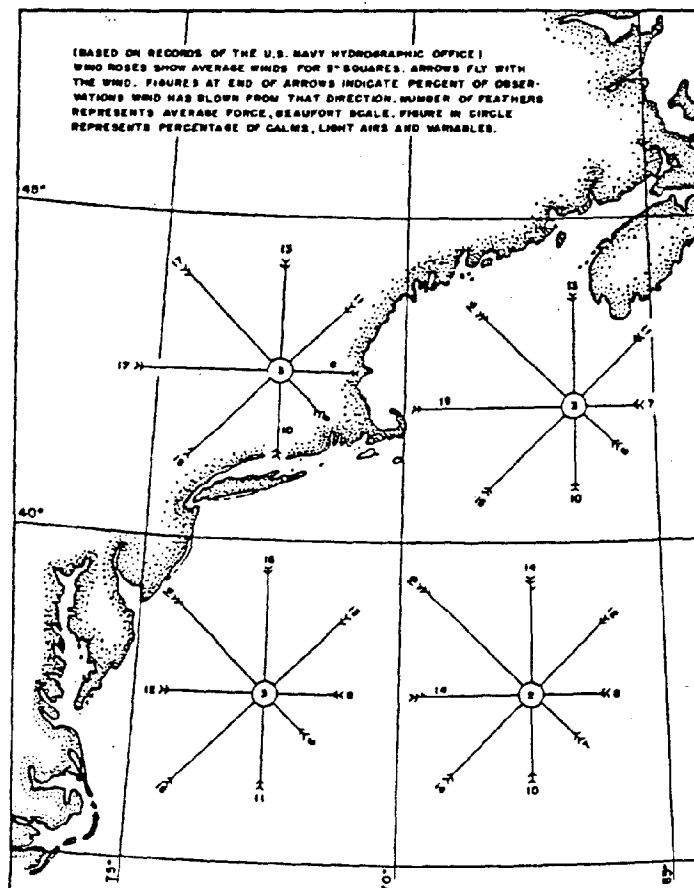
LEGEND



WAVE DIAGRAM-OFF PENOBSCOT BAY

(LAT. 43° 50' N, LONG. 68° 00' W)

SHOWING PERCENT OF TIME WAVES OF DIFFERENT HEIGHT OCCUR FROM EACH DIRECTION
 HINDCAST FROM SYNOPTIC WEATHER CHARTS FOR THREE YEAR PERIOD 1948-1950



— LOW SWELLS—(1-6 FT.)
 — MEDIUM SWELLS—(6-12 FT.)
 — HIGH SWELLS—(OVER 12 FT.)

ARROWS INDICATE THE COURSE OF SWELLS. LENGTH OF BAR DENOTES PERCENT OF TIME THAT SWELLS MOVED FROM OR NEAR GIVEN DIRECTION. FIGURE IN CENTER OF DIAGRAM INDICATES CALMS. SWELL DATA BASED ON OBSERVATIONS FOR 10 YEAR PERIOD, 1932-1942 IN THE AREA BORDERED BY THE SHORELINE, LINES OF LONGITUDE 65° AND 70°, AND LINE OF LATITUDE 40°.

PREVAILING WINDS AND SWELLS

FIGURE 7

SOURCE: Corps of Engineers, 1955

Wind Speeds and Directions (October 1949 - September 1958 inclusive)

Boston, Massachusetts
Number of Hours

Wind Speed (M.P.H.)	0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	47 & Total Over
<u>Direction</u>									
N	96	599	1,498	1,177	356	121	15	3	3,865
NNE	70	381	876	752	360	164	31	5	2,640
NE	92	485	982	1,004	523	232	87	32	3,448
ENE	92	417	777	922	434	208	54	16	2,924
E	99	453	1,249	1,216	343	128	50	22	3,562
ESE	100	543	1,448	1,263	232	67	11	-	3,668
SE	104	569	1,234	863	126	22	-	-	2,919
SSE	77	528	1,021	470	83	24	3	2	2,209
S	89	798	1,447	930	245	59	13	3	3,584
SSW	82	774	1,905	1,850	686	215	46	15	5,576
SW	93	952	3,789	4,045	1,118	268	33	3	10,301
WSW	71	569	1,910	1,981	500	95	15	1	5,142
W	73	635	1,978	2,110	835	264	69	6	5,970
WNW	73	861	2,819	3,089	1,364	510	65	11	8,792
NW	85	745	2,319	3,097	1,399	550	88	7	8,294
NNW	72	541	1,750	2,114	778	182	21	2	5,460

Portland, Maine
Number of Hours

Wind Speed (M.P.H.)	0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	47 & Total Over
<u>Direction</u>									
N	389	2,137	2,510	1,584	348	68	31	4	7,071
NNE	217	1,006	1,438	1,264	328	83	6	3	4,345
NE	134	639	785	440	133	45	3	-	2,179
ENE	109	582	729	505	130	85	31	2	2,173
E	143	712	1,081	733	161	70	27	10	2,941
ESE	146	622	758	414	66	20	4	-	2,026
SE	141	577	476	269	46	16	5	3	1,533
SSE	152	681	1,093	782	129	69	27	9	2,943
S	285	1,442	2,245	1,929	362	82	4	1	6,350
SSW	330	1,988	2,253	1,137	131	20	-	-	5,855
SW	430	2,224	1,870	618	56	9	-	-	5,207
WSW	472	2,450	1,974	1,038	261	74	6	1	6,276
W	684	3,001	2,020	1,036	290	109	9	-	7,149
WNW	599	2,683	1,962	984	256	57	4	-	6,645
NW	579	2,446	1,825	1,189	240	46	5	1	6,331
NNW	426	1,887	1,830	1,384	254	40	2	-	5,823

SOURCE: Corps of Engineers, 1962

FIGURE 8

One other important variable which controls the effect a storm will have on New Hampshire's coast is the path the storm follows with respect to the coast (Hayes and Boothroyd, 1969). A storm which remains inland has little potential for damage because the winds blow over such a small fetch. Conversely, a storm which travels well out to sea whips up waves, but has no direct impact on the coast. The waves do travel towards the coast, but their energy is dissipated somewhat by the distance between the storm and the shore. So, the route which best accommodates severe erosion is a path northeast from Nantucket, where the winds blow over a large fetch to produce large waves, but where the storm is close enough to shore to insure high impact.

The frequency of northeast storms controls to a large degree the amount of erosion which occurs over each winter (Hayes and Boothroyd, 1969). After one storm passes through, the beach immediately begins to rebuild itself. The less erosive non-storm waves redeposit sand on the beach face. If another northeast storm strikes before this replenishment can be completed, even greater erosion will result.

Storm Surge

One associated condition which occurs with storms is storm surge. Wind action on the water's surface further elevates the water level. As storm winds blow onshore, they whip the top layer of water along with them towards the shore. The end result is a buildup of water at the beach, which acts as a dam to the surge.

During a 500 year storm, or one with a 0.2 percent chance of happening in a given year, the storm surges along the New Hampshire coast are large. At the southern border, the surge would result in a water level of about 12 feet over mean sea level. At the northern end, the storm surge is estimated at less than ten feet above mean sea level (Strafford Rockingham Regional Council, 1976).

The magnitude of the storm surge which occurs during northeast storms along the New Hampshire coast increases existing erosional problems in addition to the flooding which occurs in low lying coastal areas. Storm surge heightens the effect of all storm actions by raising water level. Waves break on dunes causing undercutting, slumping, breaching, and overwashing, all due in part to the raised sea level caused by storm surge.

Tides and Tidal Currents

The tidal cycle in New Hampshire is semi-diurnal and the mean range of the tide runs from 8.3 feet at the south and 8.7 feet at the north (see Figure 4) (Corps of Engineers, 1962). Spring tides, as shown on Figure 4 vary along the same lines as the mean range, but slightly higher. Tidal variation has been recorded as the number of tides exceeding mean high tide at Portsmouth Navy Yard on Figure 4 (Corps of Engineers, 1962). These figures demonstrate that tides of up to 2.5 feet over mean high water are relatively common, but those higher than this are very rare. These high tides are caused by spring tides or storm surge.

Tidal currents affect beach development by aiding the transportation of beach material both along the coast and also into and out of marshes and estuaries. Tidal currents along the New Hampshire coast flood to the north and ebb to the south (Corps of Engineers, 1962). In addition, the currents flood into and ebb out of the estuaries along the coast.

The effect of these tidal currents is most profoundly felt in all the marshes and estuaries, especially the Hampton-Seabrook saltmarsh and the Great Bay estuary system. The velocity of tidal currents reaches a maximum value at mid-tide and a minimum of near zero within one hour of slack tide. The high velocity of the tidal currents is a result of the funnel effect. As the water flows into these inlets, the flow is constricted by the narrow width. The result is the acceleration of the water as it flows through the inlets. The maximum current at the Hampton Harbor inlet is 5.6 feet per second. At Portsmouth Harbor at the entrance to the Great Bay estuary system, the flood current is 2.5 feet per second and the ebb current is 3.3 feet per second (Corps of Engineers, 1962). Velocity at the Dover Point Bridge is probably higher than these figures judging from the greater confinement of flow.

The tidal currents in the open ocean are less vigorous yet still add to the other currents along the coast. Velocities measured off of Hampton and Seabrook by the Corps of Engineers in 1931 averaged from 1.03 to 0.45 feet per second. Further offshore, the largest velocity attributed solely to tidal currents is .20 feet per second. Currents near the inlet are influenced by the higher velocity inlet current. This influence drops off with distance away from the inlet (Corps of Engineers, 1962).

Hurricanes

Although hurricanes are extremely destructive events, their influence on the New Hampshire shoreline is limited. Most hurricanes have lost the bulk of their destructive energy by the time they reach these northern latitudes. Also, most hurricanes which travel as far north as New England, track northeast from Cape Cod. The most common influence on the New Hampshire coast is the large waves generated by the high winds of the hurricane.

In the past few decades, there has been a basic shift in the hurricane track patterns. More storms have crossed the Florida peninsula and entered the Gulf of Mexico (Godfrey, 1973). As a result, fewer hurricanes have travelled north towards New England.

The past three decades have witnessed rapid population growth of the seacoast region of New Hampshire. Many previously undeveloped, low lying coastal areas have been built upon during this lull in hurricane activity in the northeast. The consequences of a reversion of hurricane paths towards the north would have destructive impact on these coastal areas. However, the impact would be far greater in southern New England than in New Hampshire.

The line of demarcation between high and low potential damage is Cape Cod, Massachusetts. The east-west strike of the shoreline south of the Cape and east of New York escalates the probability of a direct hit by a hurricane. In addition, it increases the damage incurred by storm surge because there is less oblique attack of the wind (which occurs along the northeast) striking the New Hampshire coast. An interesting statistic which relays this concept is the storm tide of record. South of Cape Cod, the highest recorded storm tides are associated with hurricanes, whereas north of the Cape, these high tides are caused by northeast storms (Strafford Rockingham Regional Council, 1976).

Prevailing Wind and Wave Direction

Wind records are compiled at the United States Weather Bureau in Boston, Massachusetts, and Portland, Maine. The data is shown on Figures 7 and 8 (Corps of Engineers, 1962). Analysis of the records provides the conclusion that the winds blow from the westerly quadrants for the greatest duration. However, winds from the easterly quadrants are the highest velocity winds, with the greatest percentage of gale force winds blowing from the northeast (Corps of Engineers, 1962).

These onshore, easterly winds occur one third of the time, whereas the wind blows offshore two thirds of the time.

Waves breaking on the coast of New Hampshire prevail from the east and eastnorth-east. Waves from these directions occur between 20 and 25 percent of the time. Swells in the Gulf of Maine are a different matter. Low swells are common from all directions with a slight preponderance from the north. Medium swells are dominant from the northeast and southwest, with secondary domination from the south, west and northwest. High swells occur two percent of the time from the northwest and only one percent of the time from the west and northeast (Corps of Engineers, 1955).

EROSION CYCLES

Analysis of the Corps of Engineers shoreline change data reveals the variable nature of erosion and accretion along the ocean coastline of New Hampshire. The long term trend of recession is the result of the rising sea level which has followed the most recent glacial epoch. The small scale fluctuations on this long term trend are the result of variable factors such as storm frequency and intensity, strength of longshore transport, and the supply of beach materials. The short term trends are fairly consistent for the entire coast, as borne out by the correlation of changes in the shoreline between various points for each interval over the 100 year period of record.

The purpose of this analysis was twofold. The first goal was to investigate the cyclical nature of erosion and accretion along the ocean shoreline of New Hampshire. It was felt that changes in the factors producing these fluctuations would become more evident through the study of this data. In addition, it was hoped that this analysis would emphasize the dynamic nature of the shoreline and its susceptibility to short term change within the overall framework of post-glacial sea level rise.

The second goal was to investigate the possible continuity of changes along New Hampshire's coastline for each interval studied. It was felt that for the analysis to bear any merit, there must be some continuity of change up and down the coast. This possible continuity was to be investigated by correlating changes for each beach along the coast during each interval. Consistency would be evident if this situation occurred.

Methodology

Analysis of the Corps of Engineers data was undertaken in the following manner. The first step was to reduce the data from a range (i.e. 25 to 50 feet of erosion) to an average figure (i.e. here - 37.5 feet of erosion). This was accomplished and the results are displayed in Table 1. This averaging was necessary because of the eventual graphing of the data. So, for most beach sections there were four averages, one for each time interval recorded.

The second step was to plot these average changes against time on graphs. In plotting the graphs, the average change for each interval was plotted at the end point of the interval. For instance, the average change for the period from 1866 to 1912 was plotted at 1912. To aid correlation of changes between beaches, up to six beaches were plotted on each graph.

The third step was to compile a list of potential sources of error. It was felt that these potential sources of error be noted so as to accurately qualify the data. The averaging of the range of changes for each interval at each of the various beaches was the first potential source of error. Because the actual mean may have been closer to either of the extremes rather than lying at the arithmetic average of the two extremes, this calculation was a potential error.

The second source of error was the survey format. The fact that the surveys were dated by the year and not by the month allows the potential variation of the shoreline within one year to have a significant impact on the analysis. For instance, if the shoreline was mapped in the spring, it would appear recessed as a result of the erosive winter storm waves. If the same beach was surveyed later in the summer, the comparison would indicate accretion to have taken place, yet the change might be only of seasonal nature.

Despite these possible sources of discrepancy, it is felt that the data is valid for correlation. The shoreline change data of the Corps of Engineers is only available through the survey of 1959. Since that data, surveys have been conducted for several beaches, including Foss Beach, Rye and North Beach, Hampton in August, 1977, but there has been no comprehensive survey of the entire coast (Bruha, 1977).

1866-1912

Change data for this period is available for only certain beaches along the coast. There is no evidence of correlative change between beaches during these years, a phenomenon which can be explained by various methods. First, the men surveying the shoreline during this period had less sophisticated equipment at their disposal. This situation affected the accuracy of the surveys which in turn could affect any correlation of changes. The second reason explaining the poor correlation is the length of this period. During 46 years a large amount of change can occur. In using this large period for analysis, the changes which occur over a shorter period within the 46 year period are masked by the changes which occur over the longer period. Despite the poor correlation for this period, correlation does become greater for later periods.

1912-1944

The data for this period is plotted at 1944 and, as shown by the graphs, most locations experienced accretion. Correlation of changes becomes more regular to the north. Most discrepancies in correlation occur along the southern coast where the beaches, especially in Hampton and Seabrook are large scale barrier bar systems. These beaches are composed predominantly of sand with minimal bedrock exposures. Their form is very straight and linear, unlike the curved pocket beaches further to the north. The beach sand is easily transported by wave-generated currents, thus providing the mechanism for the large scale movement of beach material. Although the net transport is southerly, the actual transport varies with the direction of incoming waves. The ease of transportation, coupled with this variability in transport direction, make this area prone to large changes of short duration, explaining to some extent the poor correlation for this area. In addition, the straight nature of the shoreline here limits the modification of wave energy by refraction. Therefore, waves breaking along this expanse carry more energy than waves breaking in the smaller pocket beaches to the north where wave refraction reduces the energy level.

To the north the beach morphology consists of curved pocket beaches which decrease in size with distance north, and bordering headlands. The bedrock of these headlands has been exposed by erosion and controls the amount of erosion by virtue of its resistance to change.

1944-1953

With few exceptions, most beaches along the coast experienced erosion during this nine-year period. This erosion might be explained by an increase in storm frequency and intensity, strength of longshore transport, supply of beach materials, any other factors which might influence short term erosion or accretion.

1953-1959

During this period, most stretches of the coast experienced accretion, especially those beaches towards the north of the study area. In addition, the large amount of accretion at Hampton Beach can be explained by the beach nourishment project undertaken in 1955. A large volume of fill, obtained from dredging Hampton Harbor and its inlet, was placed at the northern extreme of Hampton Beach. Transport towards the south from Great Boars Head began immediately, so that by 1959 when the beach was resurveyed, the major accretion occurred at the middle reaches of the beach where the fill had been transported by that time. Also, some sand was transported to the north, explaining the accretion at Great Boars Head for this period.

The shifting nature of these erosion and accretion trends illustrate the dynamic nature of New Hampshire's shoreline. The numerous factors which govern the location and shape of the shoreline vary both over the short and long terms. As the rate of sea level rise slows, the long term change becomes more constant, but the forces causing the short term changes remain highly active. Therefore, it can be anticipated that changes in the near future will be short term in nature as opposed to being the result of long term recession.

TABLE I

SHORELINE CHANGE DATA

Graph 1:

	Interval	Change (feet)
Seabrook Beach (south)	1776-1855	+675
	1855-1912	+300
	1912-1928	+250
	1928-1944	+100
	1944-1953	-50
	1953-1959	+50
Seabrook Beach (north)	1776-1928	inlet migrated
	1928-1944	+100
	1944-1953	-75
	1953-1959	+50
Hampton Beach (south)	1776-1928	inlet migrated
	1928-1953	+600
	1953-1959	-10
Hampton Beach (intermediate)	1776-1855	-400
	1855-1912	+150
	1912-1928	-75
	1928-1953	-50
	1953-1959	+150
Hampton Beach (north)	1912-1928	-25
	1928-1953	0
	1953-1959	+75

Graph 2:

Great Boars Head, Hampton	1866-1953	0
	1953-1959	+100
North Beach, Hampton (south)	1866-1912	0
	1912-1944	-25
	1944-1953	-15
	1953-1959	+75
North Beach, Hampton (north)	1866-1912	irregular
	1912-1944	+25
	1944-1953	-15
	1953-1959	+25
Plaice Cove, Hampton (south)	1866-1912	-75
	1912-1944	+150
	1944-1953	+75
	1953-1959	+50
Plaice Cove, Hampton (north)	1912-1944	+25
	1944-1953	-50
	1953-1959	+35

SOURCE: Corps of Engineers, 1962

Graph 3:

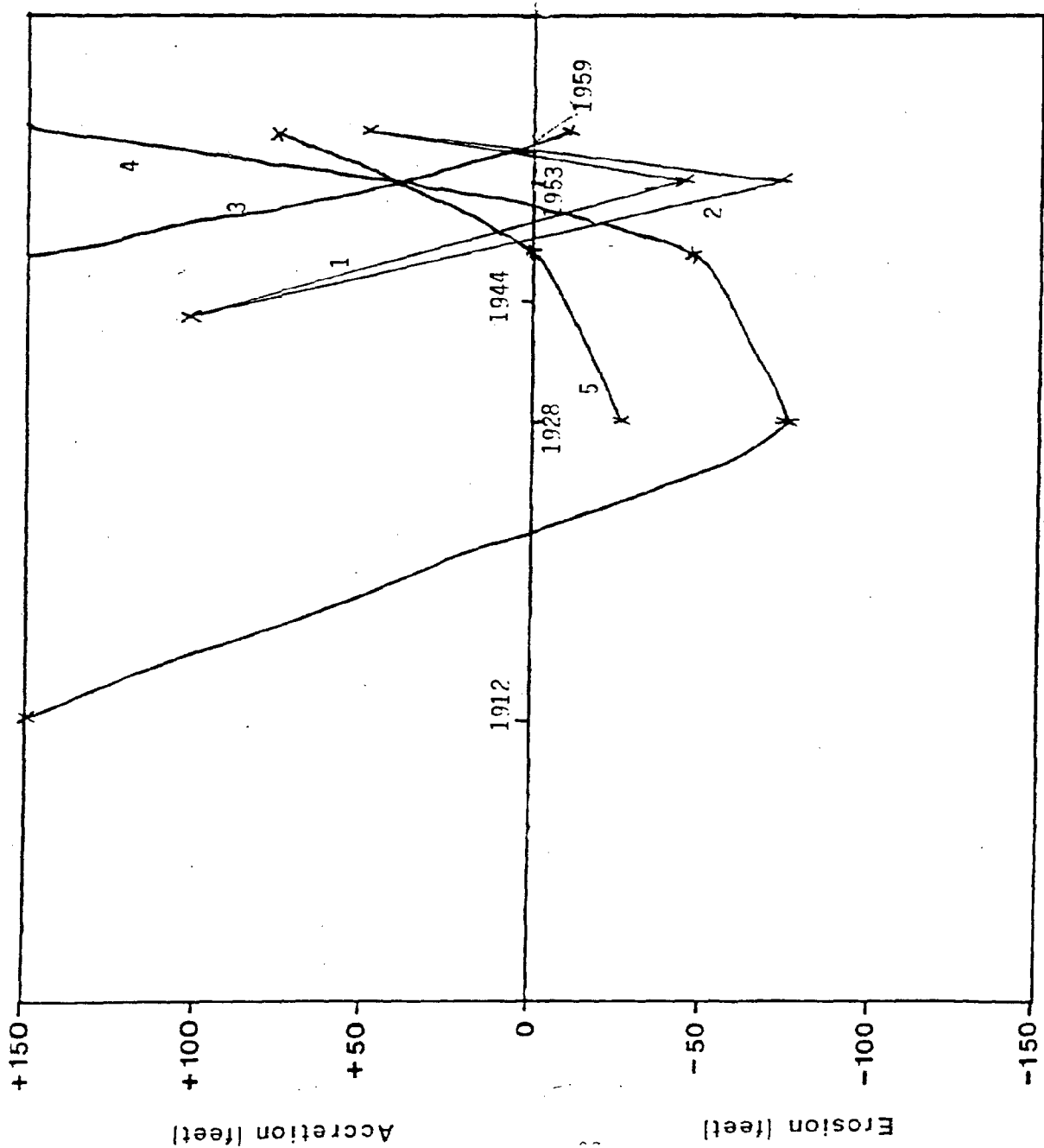
	<u>Interval</u>	<u>Change (feet)</u>
North Hampton Beach (south)	1866-1912	-25
	1912-1944	+75
	1944-1953	-60
	1953-1959	0
North Hampton Town Beach	1866-1912	0
	1912-1944	+100
	1944-1953	+100
	1953-1959	+25
Little Boars Head, North Hampton	1866-1912	+35
	1912-1944	+10
	1944-1953	-40
	1953-1959	+25
Juniper Point, North Hampton	1866-1912	0
	1912-1953	+50
	1953-1959	-25
Fox Hill Point, North Hampton	1866-1912	-25
	1912-1944	-25
	1944-1953	-15
	1953-1959	0
Bass Beach, North Hampton	1866-1912	+15
	1912-1944	+25
	1944-1953	-40
	1953-1959	0

Graph 4:

Jenness Beach, Rye	1866-1912	-75
	1912-1944	+50
	1944-1953	-25
	1953-1959	+20
Straws Point, Rye	1866-1912	0
	1912-1944	+75
	1944-1953	-25
	1953-1959	+25
Varrels Point, Rye	1866-1912	+50
	1912-1944	+60
	1944-1953	-35
	1953-1959	+60
Rye Harbor (south shore)	1866-1953	-200
	1953-1957	+40
Rye Harbor (north shore)	1866-1953	-50
	1953-1957	-60

Graph 5:

	<u>Interval</u>	<u>Change (feet)</u>
Ragged Neck, Rye	1866-1944	-150
	1944-1953	+15
	1953-1957	0
Foss Beach, Rye	1866-1944	+75
	1944-1953	-25
	1953-1959	0
	1959-1973	0
Rye North Beach	1866-1944	+75
	1944-1953	-35
	1953-1959	0
Wallis Sands, Rye	1944-1953	+75
	1953-1959	+50



LEGEND

- 1) SEABROOK BEACH (SOUTH)
- 2) SEABROOK BEACH (NORTH)
- 3) HAMPTON BEACH (SOUTH)
- 4) HAMPTON BEACH (INTERMEDIATE)
- 5) HAMPTON BEACH (NORTH)

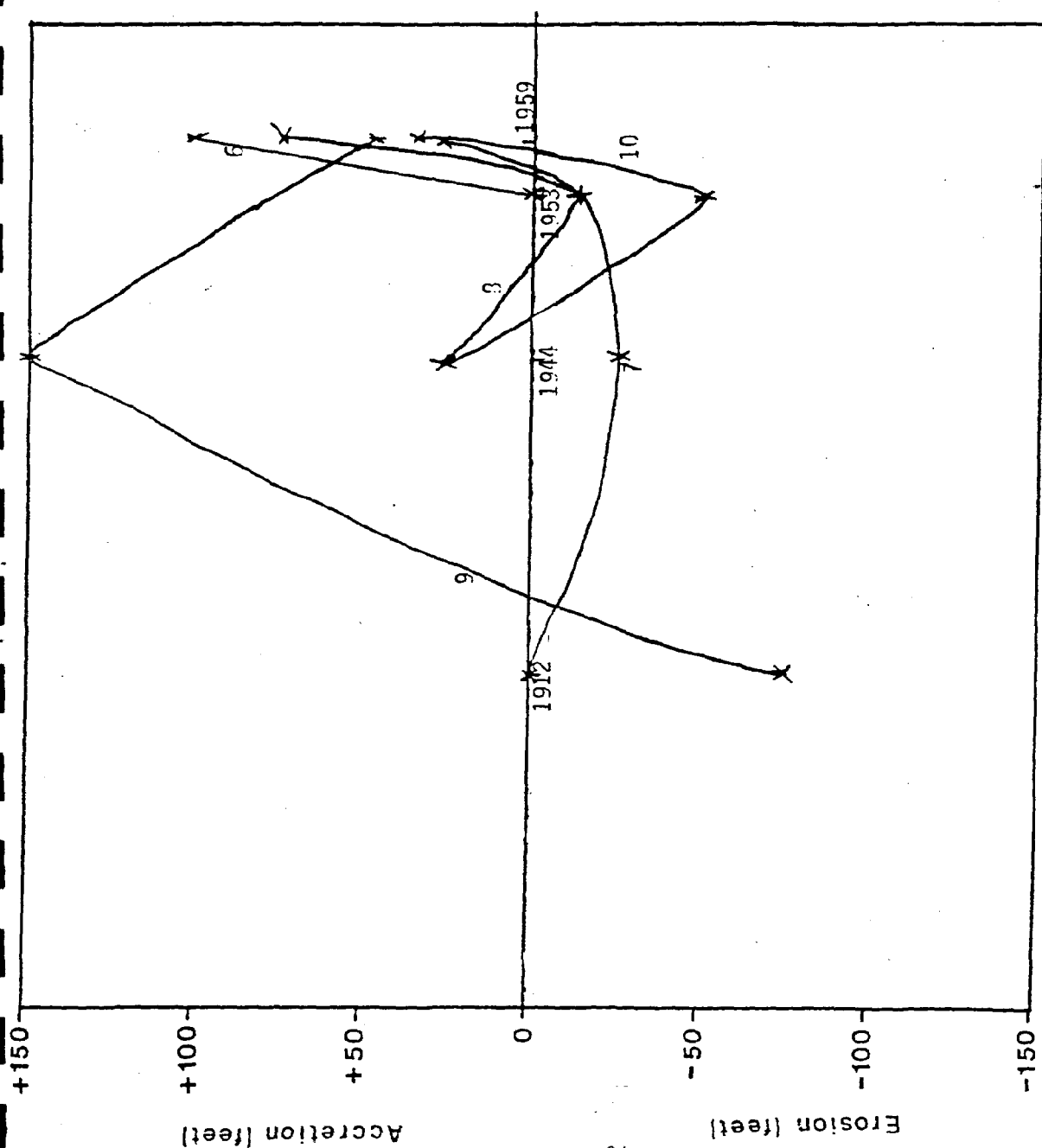
GRAPH 1

SHORELINE CHANGE GRAPHS

[Data from Corps of Engineers, 1962]

LEGEND

- 6) GREAT BOARS HEAD, HAMPTON
- 7) NORTH BEACH, HAMPTON (SOUTH)
- 8) NORTH BEACH, HAMPTON (NORTH)
- 9) PLAICE COVE, HAMPTON (SOUTH)
- 10) PLAICE COVE, HAMPTON (NORTH)



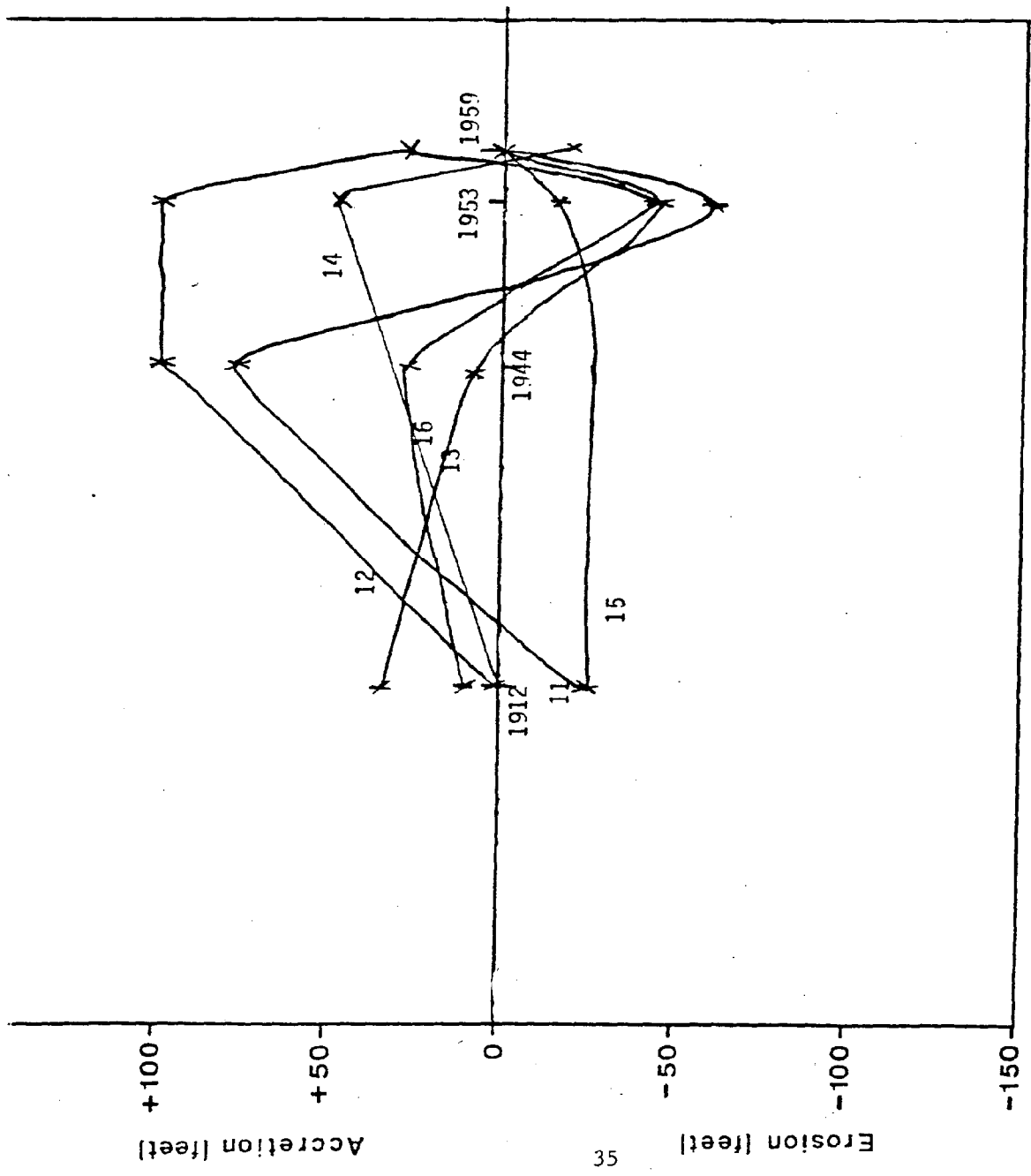
GRAPH 2

SHORELINE CHANGE GRAPHS

[Data from Corps of Engineers, 1962]

LEGEND

- 11) NORTH HAMPTON BEACH (SOUTH)
- 12) NORTH HAMPTON TOWN BEACH
- 13) LITTLE BOARS HEAD, NORTH HAMPTON
- 14) JUNIPER POINT, NORTH HAMPTON
- 15) FOX HILL POINT, NORTH HAMPTON
- 16) BASS BEACH, NORTH HAMPTON



GRAPH 3

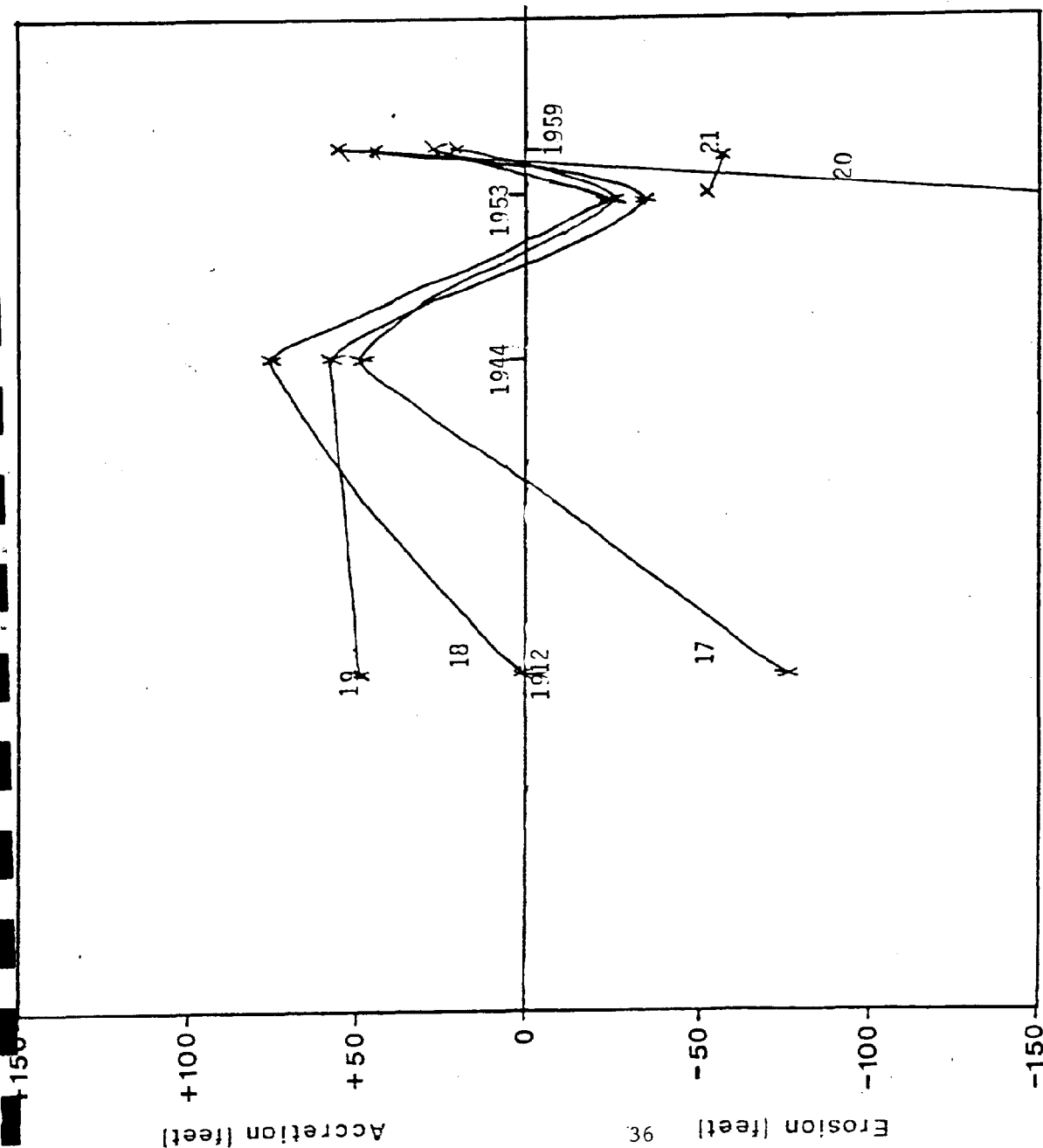
SHORELINE CHANGE GRAPHS

[Data from Corps of Engineers, 1962]

LEGEND

- 17) JENNESS BEACH, RYE
- 18) STRAMS POINT, RYE
- 19) VARRELLS POINT, RYE
- 20) RYE HARBOR, SOUTH SHORE
- 21) RYE HARBOR, NORTH SHORE

GRAPH 4

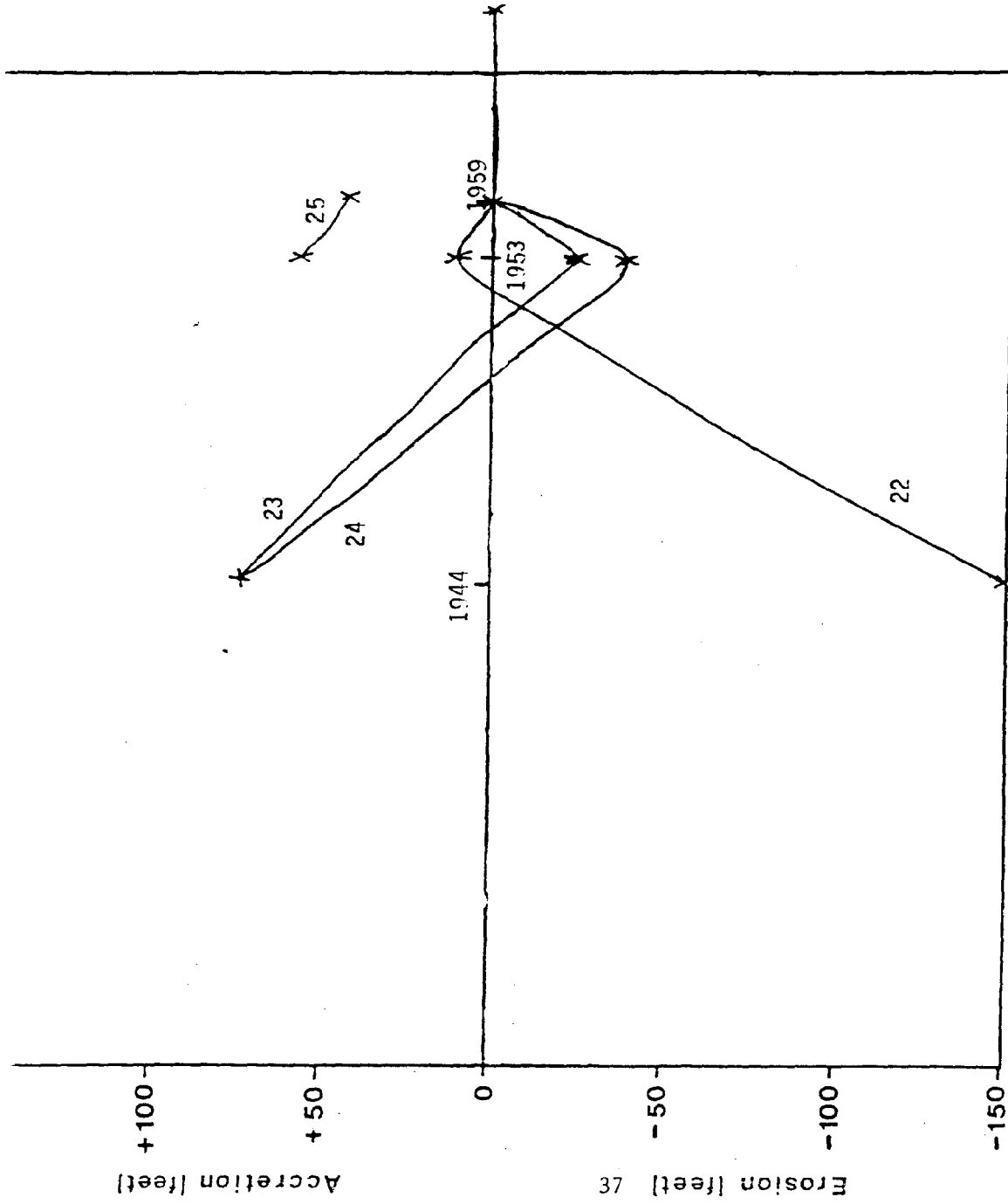


SHORELINE CHANGE GRAPHS

[Data from Corps of Engineers, 1962]

LEGEND

- 22) RAGGED NECK, RYE
- 23) FOSS BEACH, RYE
- 24) RYE NORTH BEACH
- 25) WALLIS SANDS, RYE



GRAPH 5

SHORELINE CHANGE GRAPHS

[Data from Corps of Engineers, 1962]

GENERAL COASTAL PROCESSES

SEABROOK BEACH

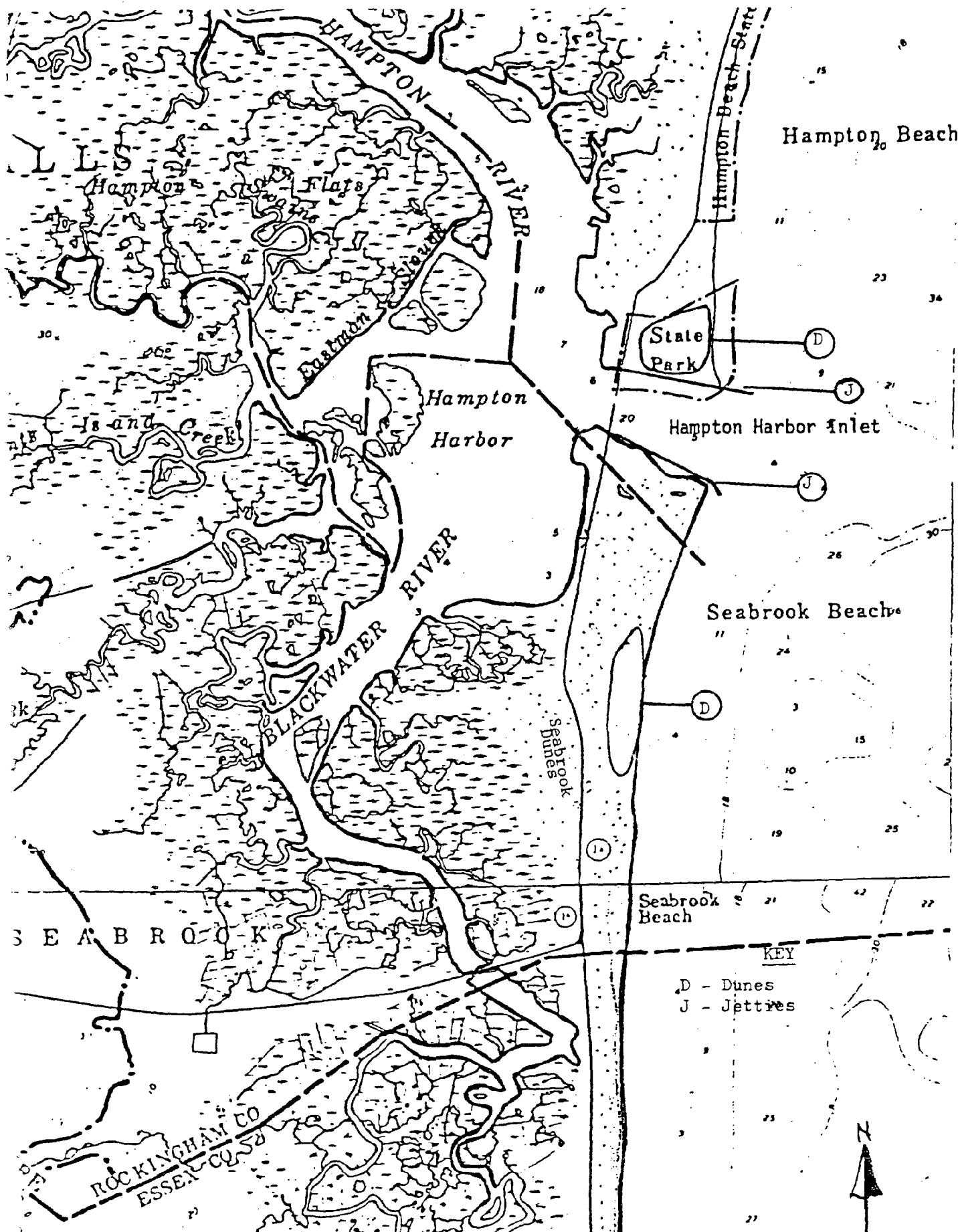
Assessment of Change

Seabrook Beach is a barrier bar extending 1.5 miles from the Massachusetts border to the Hampton Harbor inlet (See Map 5, page 39). It encloses and protects the southern extent of the Hampton-Seabrook salt marsh and Blackwater River which flows behind it. There are several stretches of sand dunes scattered along the bar. However, fifty-six acres in the southeast corner of Seabrook constitute the only remnant of a natural dune system in New Hampshire. (A typical coastal dune system consists of a frontal or foredune, a secondary or interdune, and a backdune. The foredune ridge receives the greatest impact of coastal storms; it provides initial, passive resistance to wave attack and allows breaching to dissipate wave energy. Behind the foredune, lies a more stable, yet still dynamic interdune of low, undulating sands. A backdune formation of higher dunes and deep hollows develops furthest from the beach and is characterized by shrub thickets and sunken forests.)

The dune fragments have been the object of heavy residential development. For a mile north of the state line, cottages are built on the dunes about 200 feet inland from the high tide line. Along the northerly half mile, the cottages are built directly on the seaward edge of the dunes (Corps of Engineers 1962).

Due to this extensive development, stabilization has become necessary to protect these cottages from storm damage. Cottage owners along the north end of the beach have placed riprap along the base of the dunes in an attempt to defer the erosion process. The Corps of Engineers reports that these protection structures are only about 80 feet from the high tide line and within easy reach of storm waves (Corps of Engineers, 1962).

Along Route 1A, a number of commercial enterprises and residential homes have already interfered with the foredunes and interdunes, and are encroaching on the backdune. In addition, landowners use paths through the dunes as access to the beach and vehicles secure easy access to the dunes. As a result, the beach vegetation which stabilizes the sand has been destroyed, the sand has become vulnerable to erosion, and significant portions have been washed and blown away.



Environmental Impact

Although erosion does occur periodically at the beach, it is not critical and has little impact on the economic resources of the area-except for the threat of storm waves to the cottages built so close to the high tide line. Because development and beach use are primarily residential, beach width does not affect the number of people who can use the beach. However, the erosion has an impact on the ecology of the barrier bar system.

The sand dune ecosystem is important to us ecologically for two reasons; 1) it provides a natural buffer protecting the coast from the impact of severe storms (particularly northeasters) and tropical hurricanes; 2) it provides recreational opportunities. In New Hampshire, the latter reason has been readily recognized, as the all-too-short coastal zone has experienced intense pressures from development and the pressure on this valuable resource is not likely to ease.

Because the dunes have been developed, they needed to be stabilized by various protective structures. It is these structures which interrupt the natural recession of the bar system by eliminating the overwashing and breaching caused by storm waves. Nearly all of the dune habitat has been exploited for resort related purposes. At the Seabrook Dunes, the once extensive foredune and interdune areas are now replaced by houses, summer and commercial establishments.

Seabrook has appropriated \$250,000 and anticipates receiving additional Coastal Zone Management funds to purchase the 56 acre dune system in the southeast corner of Town. Seabrook plans to protect and maintain it as it is the only remaining dune ecosystem in the state.

HAMPTON HARBOR INLET

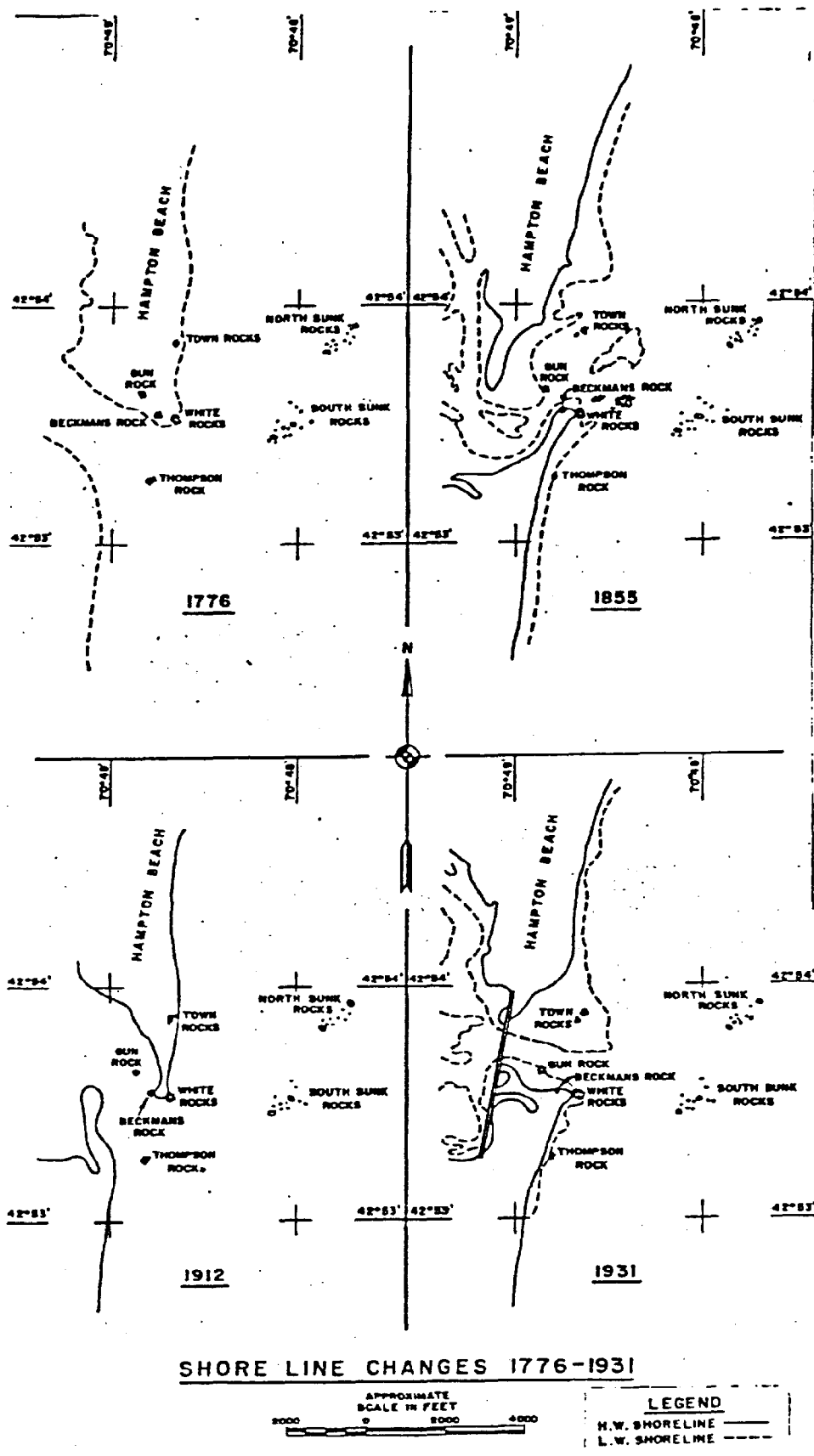
Assessment of Changes

Hampton Harbor inlet lies on the Hampton-Seabrook town line. Through the inlet, tides flush the enclosed salt marsh twice daily. The south shore extends easterly 2000 feet while the north shore is slightly shorter: 1500 feet (see Map 5, page 39).

Prior to 1935, the inlet migrated on a large scale, both north and south, as a natural response to shifting longshore transport (See Map 6). During 1934-1935, the Corps of Engineers stabilized the inlet by constructing jetties easterly along both the north and south facing shores of the inlet. While effectively stopping the migration, it also interrupted the longshore transport of sand, by trapping the sand behind the jetties. Accretion has occurred on the north side of the Hampton jetty, on the south side of the Seabrook jetty and on a bar offshore from the inlet. The Corps of Engineers suggests that this bar causes wave refraction which in turn causes a south current on the Hampton side and a north current on the Seabrook side.

The circulation is compounded by the size of the Seabrook jetty. It is a low jetty, which is overtopped by the upper reaches of each high tide. Hence, flood tide currents flow into the inlet from the south over the jetty while ebb currents flow south out of the inlet also over the jetty until the water level drops enough to expose the top of the rocks. During this overtopping period, accretion can occur on the lee side of the jetty. Sediment-laden currents pass over the jetty and can drop their sediment load if the sheltered area is quiet enough. There is probably a large amount of shuffling of sand in and out of the inlet over time, with the net flow out of the inlet and onto the beaches.

Within the channel itself, however, there has been some tidal scouring. This has become apparent in the partial undercutting of one piling under the Route 1A bridge (Oudens, 1977). The Department of Public Works and Highways (now the Department of Transportation) had placed large blocks of rock on the bottom to protect the pilings. In the 1970's and in early 1984, new stone was placed around every piling. The Department continues to monitor channel depths along the bridge in order to be aware of changes as they occur.



SOURCE: Corps of Engineers, 1955

MAP 6

Some sedimentation does occur along the edge of the channel and inside the harbor, necessitating dredging. In 1955, this dredging operation was undertaken by the Corps of Engineers to restore channel depth in the inlet and harbor. The dredged material was transported by pipe to the area of Hampton Beach north of Haverhill Street and placed on the beach in order to widen it. A similar operation was undertaken in 1965.

The changes occurring in the inlet have been reduced since 1935 when the jetties were built. Prior to this construction, migration of the inlet north and south was the major change. Now shifting of shoals, scouring of the channel, and sedimentation in quiet areas are the primary changes which occur regularly.

Environmental Impact

Shoreline changes at the Hampton Harbor inlet have had definite impact on the resources of the coastal zone. These impacts have been both beneficial and adverse in nature and by and large have depended on man-made changes.

The channel under the Hampton Harbor Inlet Bridge is very narrow and the receding, or "ebb" current is exceptionally strong through this narrow channel. For this reason, sand had previously been "scoured" or taken away from the base of the bridge pilings by the tide, rendering them unstable. In early 1984, the Department of Public Works and Highways placed a substantial amount of boulder rip rap at the base of every abutment. This served to protect the pilings but also effectively reduced the volume of the already narrow channel. As a result, the current in mid-channel under the bridge became more rapid, and the current on both sides of the channel slowed considerably. Therefore, deposition increased on both sides of the channel just east of the bridge. Obviously, this has made the already challenging navigation of the channel even more difficult.

The inlet migrated frequently prior to stabilization in 1935, causing major navigational problems. The stabilization project was undertaken with the goal of easing these navigational hazards. This goal was met with general success, and so had a beneficial impact on navigational safety. However, the construction of the jetty has caused several problems.

First of all, by stabilizing an inlet, man attempts to control a highly dynamic area which is in a state of constant change. Although the inlet is effectively

stabilized, all the forces which had caused the prior migrations are still active.

For this reason periodic dredging of the harbor and parts of the inlet becomes necessary. This dredging has several adverse effects on the estuary. It kills most shellfish in the dredged material, kills the vegetation which stabilizes the sediment on the bottom, liberates fine particles into suspension which can smother shellfish and plants in other areas, and affects the circulation patterns in the dredged area. Again, dredging does have the beneficial impact of increased safety, but it must be performed periodically at great economic and ecological expense.

Another result of the jetty construction is the effective removal of the inlet area from the influence of longshore currents. One consequence of this interference is the inadequate removal by tidal current of deposited material. When more material is carried into an area than is removed, accretion occurs. This accretion, in light of the need to keep the channel navigable, can become a hazard and require removal, setting up all the adverse effects of dredging.

The impact of dredging is felt by the shellfish industry as well as by the ecology of the estuary. During the dredging process seed as well as adult clams are destroyed at the dredge site so that the impact is felt not only immediately but also over the long run. The increased turbidity and suspended solids can smother other shellfish many miles from the dredging site when the particles settle out of suspension. Even a thin layer of sedimentation can kill seed clams and render the area unsuitable for future use as a clam nursery (Clark, 1974).

The dredging is necessary to aid navigation in and out of the harbor, and hence benefits the recreational boater. Dredging has also increased the mooring space available, allowing the economy of the area further income.

The stabilization of the inlet has affected various resources of the area. Most of the adverse ecological impacts are the result of dredging which is necessitated by shoaling within the inlet and harbor.

HAMPTON-SEABROOK SALTMARSH

Assessment of Changes

The Hampton-Seabrook saltmarsh is the marsh area protected by the Hampton and Seabrook barrier bars. The marsh is fed by the Hampton and Taylor Rivers to the north, the Blackwater River to the south, and various small streams along the western shore (See Map 5, page 39). The marsh is flushed by the tides twice daily through the Hampton Harbor Inlet, so circulation within the marsh is adequate. The circulation is augmented by the fact that Blackwater River connects with the marsh behind the Newburyport, Massachusetts harbor. So, the marsh has two effective inlets which aid the tidal flushing action.

Erosion within the saltmarsh is not a major problem. The tidal currents do scour the channels as they flow in and out resulting in some erosion of the bottom material and peat from the banks. Often the current undercuts banks resulting in the slumping of peat chunks into the water. This erosion action occurs continuously throughout the marsh and is not of major importance, with respect to impact on the natural resources of the saltmarsh.

Other erosion which takes place is caused by the freezing of the top layer of water in the marsh in the winter. When the water freezes the bank also freezes, often directly to the ice on the water. As the tide rises and falls, the ice does also, and any peat which is frozen to it will become dislodged. The peat is then rafted by the ice until melting occurs.

Accretion is a natural occurrence in an estuary. The rivers feeding the marsh carry with them a load of sediment. Because the estuarine environment is well protected, the current velocity is low and much of the sediment carried into the marsh is deposited. So, the estuary acts as a sediment trap at the end of the rivers which feed it, preventing most of the sediment from reaching the littoral zone.

Environmental Impact

These natural processes have little adverse effect on the natural resources of the saltmarsh. However, man-made disturbances have had serious impact on these resources. Dredging and construction have caused the greatest impact.

Construction has much the same effect of churning up the bottom sediments and hence causes the same problems.

There have been major changes in the submarine topography resulting from natural causes. In 1930, a destructive fungus which attacked eelgrass was transported from Europe. This fungus virtually wiped out the entire crop of eelgrass along the New Hampshire shoreline. This had widespread ecological impact because eelgrass has a massive root system which stabilizes the sediments on the bottom. Once the plants died and rotted away, there was no remaining stabilizer for the sediments. Massive slumping and shifting of shoals occurred which resulted in extermination of many organisms living in the marsh bottom. The freed sediments were washed back and forth over the channel beds by the tides, covering clam beds and fish spawning grounds (Jackson, 1944).

When the eelgrass reestablished itself in the 1950's, stabilization occurred under slumped conditions. The major channels had remained clear by virtue of the high current velocity which flowed through them. However, the minor channels remained in slumped condition and were stabilized as such. The major topographic effect on the region of this eelgrass demise has been the obliteration of small channels and massive shifts in the shoal distribution of the saltmarsh.

HAMPTON BEACH

Assessment of Change

Hampton Beach stretches almost two miles from the Hampton Harbor inlet north to Great Boars Head (See Map 5, page 39). It is sand beach for its entire length with the exception of outcrops of bedrock at the northern end. It is a barrier bar which has grown south from Great Boars Head to the Hampton Harbor inlet. The original bar morphology is similar to that at Seabrook.

Seabrook's development is predominantly residential with cottages built directly on the dunes -- at least remnants of the dune system are still present. At Hampton there is no existing evidence of dunes, with the exception of a small area at the south end of the state park, adjacent to the inlet. (The former backdunes area has been leveled, filled, and packed for use as a parking lot. Rip rap stabilizes the shore along the inlet to prevent erosion.) The development at Hampton Beach consists largely of motels, hotels and other tourist-based establishments.

In order to protect this large investment from the onslaught of the sea, the State of New Hampshire constructed a seawall in front of the business center

during 1946-1947. The state also placed a riprap revetment at its base along the southern sector (Corps of Engineers, 1962). As is the case with the riprap at Seabrook, the seawall structure has hastened erosion, rather than retarding it. During storm activity, waves break directly on and over the seawall.

While a dune provides initial, passive resistance to wave attack but allows breaching to dissipate wave energy, a seawall stands firm. The seawall concentrates the breaking wave's energy at its base and promotes scouring of the beach face. In fact, at the northern end of Hampton Beach, northeast swells are reflected by the concave seawall in a southerly direction, hence adding to the erosive force of the longshore current (Hayes, 1969) (See Figure 9, page 48).

Due to the orientation of the beach and to the refraction of the waves around Great Boars Head, the longshore transport at Hampton Beach is in a southerly direction. Therefore, beach material generally comes from the north. The angle of approach or "incidence" of the oncoming waves is an important variable in determining the direction of longshore transport.

When the beach was forming originally, much of the beach materials came from offshore glacial deposits. The coarser material was left in place offshore, while the finer material was transported towards shore and deposited on the beach. Erosion has depleted most offshore sources of transportable material. Therefore, most beach material must originate from onshore sources (McIntire and Morgan, 1964). The major onshore source has been Great Boars Head which lies at the northern extremity of Hampton Beach.

Wave energy is concentrated around headlands, such as Great Boars Head, because wave refraction effectively bends the waves in towards the headland from all sides. The result is rapid erosion, especially of Great Boars Head, an unconsolidated glacial deposit. Waves breaking on Great Boars Head carry the smaller, lighter sediments in a southerly direction along Hampton Beach (and, in a northerly direction along North Beach). The larger sediment is dropped in place and transported only by waves large enough to move it. This results in a higher percentage of cobbles and shingles at the northern end of Hampton Beach and around Great Boars Head than farther south along the beach.

Once Great Boars Head was built upon, there was a great need to limit erosion of this headland. Erosion had been controlled to some degree by the larger

BEACH PROFILES STATION HBB, HAMPTON BEACH HAMPTON, N.H.

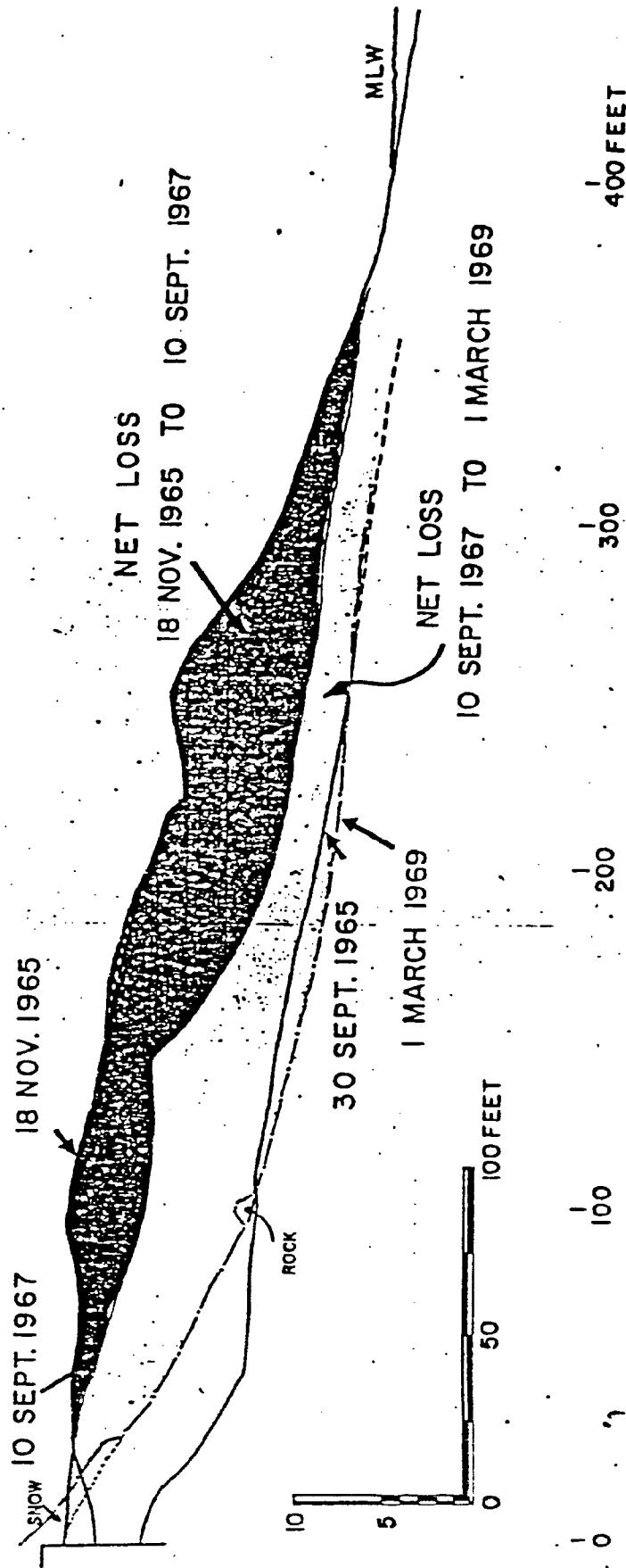


FIGURE 9 SOURCE: Hayes, 1969

boulders which had been eroded and dropped in place, but it has been further reduced by the construction of riprap revetment around the entire point.

This situation has effectively halted the supply of material from Great Boars Head to Hampton Beach. The longshore current, however, still continues to flow south and accordingly transports material from the north to the south. The result is erosion at the north part of the beach, because material is removed but not replaced.

In response to a recommendation from the 1953 Corps of Engineers study, Hampton Harbor inlet was dredged and the fill placed at the north end of Hampton Beach. The operation was completed during 1955 and had a dual purpose. The dredging was undertaken to improve navigation in the inlet where shoaling had cut down the width and depth of the channel. The dredged material was placed on the north section of the beach because the large loss of sand there was severely limiting the recreational use. A total of 101,000 cubic yards of fill was placed on the beach as a result of this operation. When the filling was completed, the waves began to rework and transport the sediment. By January 1959, an estimated 80,000 cubic yards had been eroded from the fill area and transported to the south or offshore (Hayes, 1969).

In the fall of 1965, under state and federal auspices, a similar, yet more extensive operation was undertaken. Two hundred, fifty thousand cubic yards of fill was dredged from Hampton Harbor and placed at the same location, north of Haverhill Street. This operation was monitored by the University of Massachusetts Coastal Research Group. Their periodic profiles, show that most of the material placed on the beach had been removed by wave action by the spring of 1969 (Hayes, 1969).

Again, in 1973, this same operation was undertaken. At this time, as in the past, material dredged from Hampton Harbor was hydraulically pumped to the north end of Hampton Beach, adjacent to Great Boars Head. Some of the dredged sand was placed in trucks and transported to Wallis Sands Beach where it was dumped as fill at the State Park (Carpenter, 1978). The total volume dredged was 130,000 cubic yards. In 1974 the state dredged the mooring sites in the harbor.

It is ironic to note that much of the dredged material deposited at the north section of the beach was transported south, and eventually was redeposited in

Hampton Harbor. These dredge and fill operations are in effect recycling the sand deposited in Hampton Harbor to its point of origin.

Environmental Impact

The erosion of Hampton Beach has had an adverse effect on the recreational use of the area. Erosion has limited beach use, especially at the northern end by reducing the width of the beach. This beach is used heavily during summer months as a bathing beach and the reduction of the beach area has caused crowding and actual reduction of the number of people able to use the beach.

The Hampton Beach area relies heavily on the tourist industry. A reduction in the use of the beach area results in a loss of revenue. This factor prompted the dredge and fill operations of 1955 and 1965.

While helping the economic and recreational aspects of the beach, the transporting of sand had an adverse effect on the ecology of the area. The sand, when dumped on the beach and offshore, smothers any organism unable to avoid the massive dumping. Shellfish, fish, and plant life are all affected by the fill operations by the dredging, dumping and by the subsequent movement of sand.

In an attempt to limit the damage caused by storm waves, the seawall was constructed along the back side of the beach. This seawall, while providing some protection to the road and adjacent buildings from storms, has impaired the aesthetic value of the area. In addition, the reduction of beach width has also lessened the scenic appeal of the beach area.

GREAT BOARS HEAD

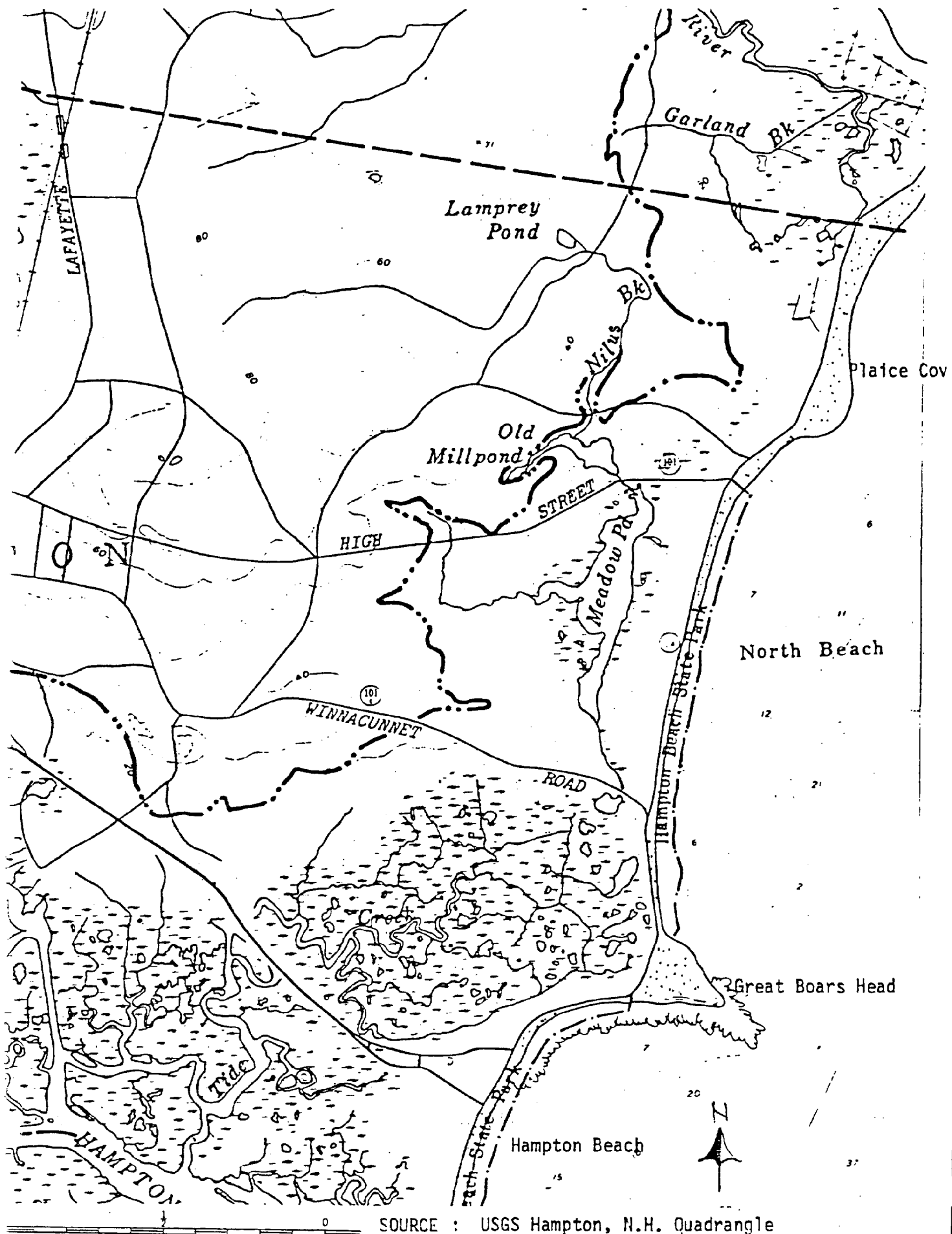
Assessment of Change

Great Boars Head is a drumlin -- an oval hill formed from material left by a glacier -- located between Hampton Beach on the south and North Beach on the north (See Map 7, page 52). It consists of unconsolidated glacial till with an equal proportion of fine and coarse fractions. It protrudes several hundred feet into the sea. The cliff, or "scarp" at the seaward end is 40 feet high (Tuttle, 1962).

Due to its unconsolidated nature and its protrusion into the sea, Great Boars Head has been attacked by waves most vigorously. The scarp is undercut by wave action and the unstable bank subsides. The slumped material is then further reworked by waves. While this reworking takes place, all but the coarsest fraction of the till is removed. These boulders were left close to their original positions within the drumlin and have been moved very little even by the waves of intense northeast storms. These "boulder pavements" give a very good estimate of the original extent of the drumlin (Tuttle, 1962). The pavements show a minimum of 100 feet erosion on the north and south sides and much more on the point. Hitchcock noted in his 1898 chronicle that the tip of Great Boars Head had eroded many hundreds of feet from 1650 to 1850 (Tuttle, 1962).

Wave attack on the drumlin causes conflicting longshore currents. Oncoming waves are refracted towards the headland and break obliquely to it. On the south side of the head this sets up a southerly current. On the north side it sets up a northerly current. As mentioned previously, the concentration of energy due to this refraction causes large scale erosion. The finer fraction of this eroded material is transported by the currents north and south from the head.

This sediment flow was the major source of beach material for both Hampton and North Beaches. The supply was severely impaired when the State of New Hampshire stabilized the shore of Great Boars Head with a riprap revetment. This stabilization became necessary due to increased residential development directly on the drumlin. The original protective structure was placed during 1955-1957, and has been refortified several times since (Corps of Engineers, 1977).



SOURCE : USGS Hampton, N.H. Quadrangle

MAD 7

This stabilization project incurred a drastic reduction of material available for the transport mechanism, however, so the oncoming waves continue to pick up sand from the beaches fronting the head and transport it away from the head. This results in a deficit and thus in erosion, most noticeable on the areas of the beach adjacent to Great Boars Head.

Environmental Impact

Prior to stabilization, in 1955, the erosion occurred at a faster rate than at present. The retreating scarp had an adverse effect on the land owners who were losing their land to the sea. Stabilization by construction of riprap around the point helped solve this problem, but caused another.

The stabilization has affected both the ecological and recreational resources by removing a source of beach material from the sand budget. Without Great Boars Head to supply sand to Hampton and North Beaches, the width of these beaches has decreased causing detrimental impact on the recreational use of the beaches. In much the same way that stabilization has impaired the recreational use of the beaches, it has interfered with the ecology of the coastal area by eliminating this source of beach sediment. In a natural system, the sea attacks and erodes the headlands, and deposits the material in the pockets between headlands. The end towards which the system is striving is an equilibrium where there are no headlands or coves, just a straight linear beach. While there are too many variables present for this equilibrium position ever to be reached, interference in the process does upset the natural pursuit of this equilibrium position.

NORTH BEACH

Assessment of Changes

North Beach is in Hampton, 1.7 miles long, and runs from Great Boars Head on the south to Plaice Cove's headland on the north (See Map 7, page 52). It is a closed barrier bar, totally enclosing Meadow Pond. All but the northern .2 mile is part of Hampton Beach State Park.

Development at North Beach is similar to that at Hampton Beach, with the exception of width. The development here at North Beach does not encroach upon the

marsh as much as the Hampton Beach development, but both occupy the site of previous dunes. As at Hampton Beach, the development required protection which was provided by the construction of a concrete seawall during 1934-1935 along the north section of the beach. Later, during 1955-1956 a sheet pile bulkhead was built from the pre-existing seawall south to Great Boars Head. In addition, a shore apron was laid down along the concrete seawall and seven groins were constructed perpendicular to the wall. Large armor stones were placed at the base of the steel seawall to prevent undercutting (Corps of Engineers, 1977).

Prior to construction, the beach consisted of a shingle ridge on the backshore and variable amounts of sand in the foreshore. (Tuttle, 1962). The ridge was flattened out when the steel seawall was built. This provided a wider beach, and a lower profile. At the present the beach material varies from the shingles at the south to sand mixed with gravel at the north. Bedrock begins to crop out more frequently to the north adjacent to Plaice Cove (Corps of Engineers, 1977).

Before shore stabilization, the material on North Beach was transported from Great Boars Head on the south and from Plaice Cove on the north. The general direction of transport is toward the center of the beach from the bordering headlands (See Map 7, page 52). This transport is explained by refraction of the incoming waves by the headlands and the commencement of a longshore current away from them. Once these headlands were stabilized they could no longer provide material for beach formation. Since waves still attack the beach, material continues to be transported. Now it is not replaced and loss of beach material results.

There are other factors which contribute to the erosion problem at North Beach. In addition to the reduction of incoming material, the stabilizing effect of the full length seawall on the natural recession of the barrier bar has been detrimental to the beach. As the recession proceeds, the shoreline moves landward towards the seawall, but the seawall cannot move. Hence, the beach becomes narrower due to the seawall's immobility and its inability to supply sand to the beach as a dune would.

Also a factor in the erosion problem is the concentration of energy which occurs on a seawall when waves break on it. Not only is all the energy of the wave released directly on the seawall, but some of the energy is reflected down

towards the beach and back towards the ocean. This reflected energy can carry away large quantities of beach material.

The result of these various factors is massive erosion which has left North Beach so narrow that it serves none of the natural protective functions of a beach. High tide storm waves send water crashing over the seawall, carrying with them kelp, cobbles, and sand. The seawall and road cannot be subjected to such wave action much longer before severe damage is incurred.

Environmental Impact

The impact of the erosion at North Beach has been extreme on both the recreational and economic resources associated with the beach. The erosion causes a large decrease in beach width, the steepening of the profile of the beach, and a change in beach material from fine sand to extremely coarse cobbles. The result is the virtual elimination of North Beach as a viable bathing beach. The width is so diminished that at high tides waves often wash up to and over the seawall.

The economy of the area suffers because few people can use the beach, despite the heavy demands for recreational use. This situation contributes to the problem of overcrowding at Hampton Beach by people who might have used North Beach. Hampton Beach is not only beset by its own erosion problem but also by the increased tourist traffic from those people unable or unwilling to use North Beach. Another economic impact of the erosion is the problem of clearing the road behind the seawall of debris after each storm. Cobbles, seaweed, and water are deposited across the highway as storm waves overtop the seawall and carry this material with them.

The erosion has had an impact on the aesthetic value of the beach. The seawall is unsightly enough, but a beach of large cobbles barely visible at high tide is hardly as attractive as the wide sand beach North Beach once was.

PLAICE COVE

Assessment of Changes

Plaice Cove is a headland area which borders North Beach on the north (See Map 7, page 52). Its southern end is a promontory which protrudes slightly into the sea. This headland is composed of a bedrock core covered by a layer of glacial till. To the north grows a barrier bar which encloses the salt marsh fed by the Little River. The entire point runs for .75 mile north from North Beach to North Hampton Beach, at the North Hampton town line.

The actual headland area on the southern extent of Plaice Cove has provided much of the material for the beaches flanking it. Despite its large bedrock core, there is enough glacial till in the mantle to provide fine grained material to the beaches. The erosion of the headland is controlled by the bedrock core's resistance to wave attack. In this case, there was much material liberated during the initial wave action on the till. As waves first cut into the headland as a result of post-glacial sea level rise, there was much glacial material available to be reworked. However, now that the sea level has reached a relatively constant level, no new glacial material is liberated and the bedrock, in effect, protects the remaining mantle of till by resisting erosion.

During the primary erosion, the waves and wave generated currents carried off the finer fraction of the till, leaving the boulders in place. These boulders give both an estimate of the original size of the headland and some protection from oncoming swells. The finer material has been transported south and north away from the head (Tuttle, 1962).

Environmental Impact

The impact of recent shoreline changes at Plaice Cove have been minimal. Long term changes have included a large amount of erosion of the headland and the ensuing desposition to the north as a barrier bar. However, the recent changes have been small and inconsequential, due in part to the fact that the sea level rise has slowed significantly during the past century, and that the shoreline has been more stable in recent geological history. Accordingly, the impact on the resources of the area has been inconsequential.

NORTH HAMPTON BEACH

Assessment of Changes

North Hampton Beach is an extension of the Plaice Cove, Hampton barrier bar into North Hampton. It abuts Little Boars Head on the north and is close to .5 mile in length (See Maps 7 and 8, pages 52 and 59).

Dunes on the barrier bar have been heavily developed for residential use. This large monetary investment has required protection against the sea. This protection was provided by a concrete wall (Corps of Engineers, 1962). Since 1962, this beach has been accreting from both on and offshore sources. Historically, changes in the shore line are erosional at the southern headland and accretional at the northern barrier bar section (Corps of Engineers, 1962).

Beach material varies from fine sand to sand with interspersed gravel and cobbles. Sand is common offshore, and outcrops of bedrock are common at the southern end of the beach (Corps of Engineers, 1962). Seasonal changes reflect an increase in the wave energy during the winter. Finer particles are removed from the beach face, placed offshore as a bar, and replaced during the calmer summer season. At the north, the upper beach consists of a shingle ridge, while the fore shore is composed of finer material. To the south there is a large boulder pavement located midway between Plaice Cove and Little Boars Head. There is no remaining headland here, but the boulder pavement is evidence that a massive glacial deposit once existed at this position (Tuttle, 1960). There is no bedrock core in evidence which would have slowed the rapid erosion which has occurred here. The erosion of this deposit has provided much of the material which formed the barrier bar.

This boulder pavement influences the longshore current at this location. The predominant direction has been from south to north, but the presence of the boulder pavement has changed the wave generated currents in its vicinity. Waves breaking on the pavement are refracted so as to form currents north and south away from the pavement.

The growth of the barrier bar across the marsh has made some radical changes in the marsh's drainage pattern. The marsh formerly underwent tidal flushing action through an inlet at the middle of the beach. This inlet has migrated

300 feet north as a result of the northerly longshore current. Aerial views show the channel bed to be 75 feet wide (Tuttle, 1960).

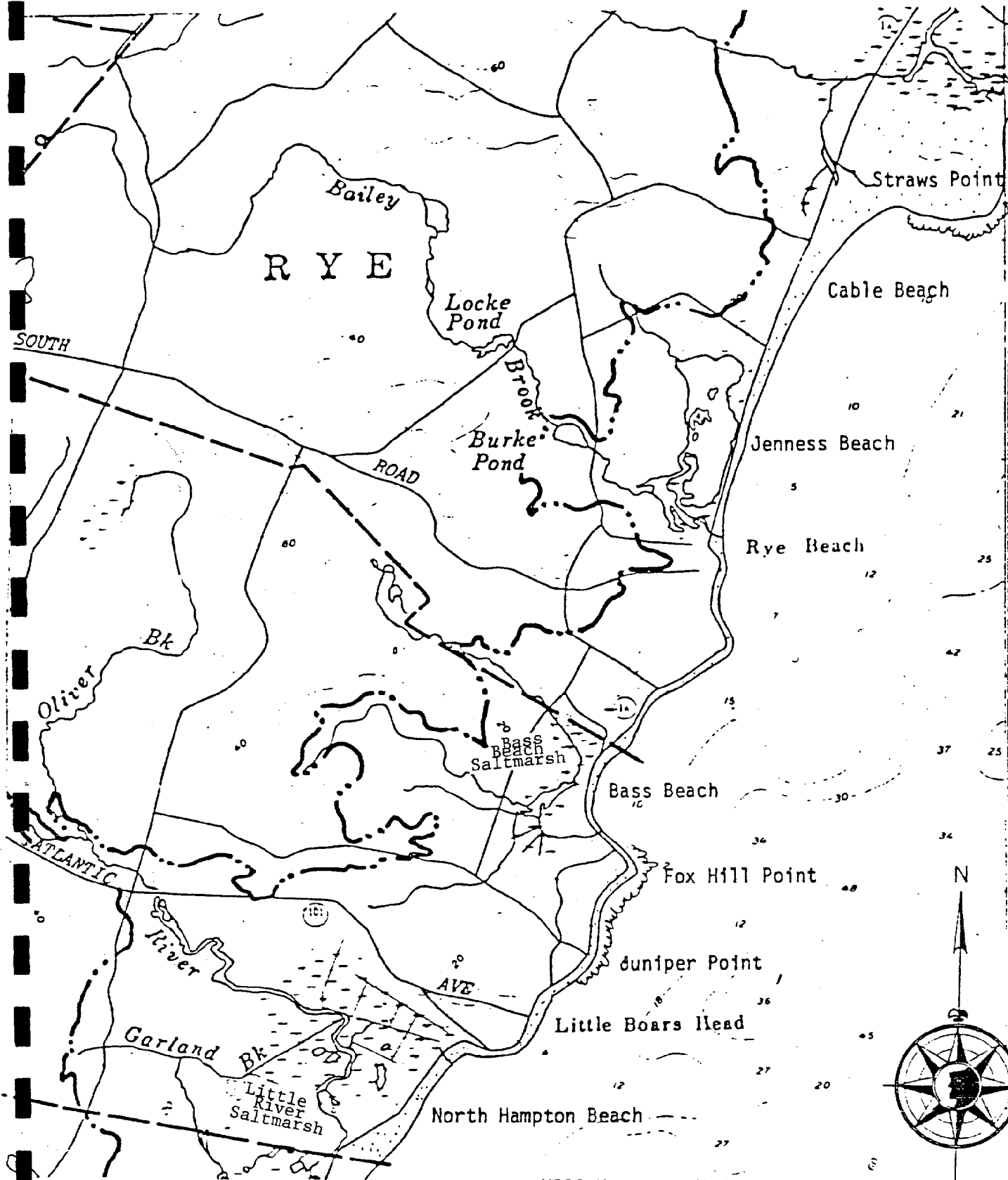
The longshore transport has moved enough sand into the inlet to close it off. The state constructed a four foot culvert at the north end of the marsh to allow drainage (Corps of Engineers, 1962). Both the flood of tidal water and the flow from Little River are restricted to this, the only open connection between the marsh and the ocean. Prior to this construction, the marsh drained naturally with the tides only when the water level rose high enough within the marsh to breach the bar. Subsequent to culvert construction, all of the drainage has occurred through the culvert near Little Boars Head.

Environmental Impact

The alteration of the inlet configuration to the Little River saltmarsh has been the major change in this area. While it is unclear how much effect man has had on the closing of the natural inlet, he has definitely changed the natural process by constructing the culvert at the north end of the beach.

The culvert has restricted the flushing action of the tides which was satisfactory when the inlet was open. The problem is that there is not enough flushing of saline tidal ocean water up into and then back out of the marsh. During a normal tidal cycle of twelve hours, ocean water cannot reach the far end of Little River Marsh and drain back out. It is this flooding and draining of salt water that creates the characteristic salt marsh flora and fauna - from the smallest benthic alga and crustacea to the more noticeable cordgrass and racoon (Short, 1984). At the little River Marsh, the single culvert under the fish houses at the north end of the marsh is inadequate to flush the marsh system.

The lack of tidal flushing is exacerbated by the blocking of the old channel under the bridge on Route 1A. It is doubtful that this channel ever carried much ocean water into the marsh (except when newly reditched, as it was annually before 1950). It did, however, certainly drain the freshwater out, thereby allowing more salt water to penetrate the upper reaches of the marsh through the culvert by simple displacement. (Ibid).



SOURCE : USGS Hampton, N.H. Quadrangle

MAP 8

There are other culverts and bridges within the marsh that restrict flushing. The development of Fifield Island and the associated roads have all brought hydrological changes. Each of these culverts and other "improvements" must, at the time it was built, have seemed to be a minor undertaking -- unlikely to have significant impact. However, the long term cumulative effect is great.

The subsequent decrease in salinity in the marsh has caused the invasion of terrestrial and freshwater marsh plants. The most obvious and aggressive of these is purple loosestrife which now covers approximately 60% of former marsh area (Ibid). Loosestrife is not productive of the detrital material so essential to the food web of the marsh. It does not attract birds or animals and acts as a barrier to protective habitat for wildlife. The invasion of purple loosestrife is a sure indicator of degradation and loss of salt marsh area. In the event of the insurgence of salt water through a breach during a storm, the rapid rise in salinity would be tolerated by the original marsh plants, but it would kill most of the fresh water invaders (Richardson, 1977).

In addition to the changes which have occurred to the vegetation as a result of the reduction of salinity, the shellfish population has also been affected by the fresh water. Most salt water organisms need a certain concentration of salt in the water to survive. When the salinity falls below this level, there is a large decrease in the shellfish population.

The construction of the culvert and closing of the inlet have had an adverse impact on the ecology of the saltmarsh, and the potential is present for far greater damage to occur, such as total eradication of shellfish and ultimately the total breakdown of the saltmarsh community.

LITTLE BOARS HEAD, JUNIPER POINT, FOX HILL POINT

Assessment of Change

The promontory located directly north of North Hampton Beach consists of three distinct points, Little Boars Head, Juniper Point, and Fox Hill Point (See Map 8, page 59). The southernmost is Little Boars Head which is a drumlin with a small bedrock core (Tuttle, 1960). It is higher in elevation than the other two points and its shoreline extends for 1700 feet (Corps of Engineers, 1962).

The bedrock core has controlled erosion here, so that the highest point on the drumlin still exists. The land slopes down towards the water in evidence of this fact. There is a wave cut below the road at sea level.

There are boulder pavements around the point outlining the erosion changes which have taken place there. Refracted swells have carried the sand fraction of the till south to North Hampton Beach and to the north around the point to Bass Beach. Remaining on the beach, in addition to the boulder pavement, are shingles and cobbles. Hence the beach material is very coarse, with the exception of a pocket of sand along the south limit (Corps of Engineers, 1962). Bedrock crops out along the exposed extent of Little Boars Head and is covered by boulder pavement.

Stabilization of this headland was attempted in 1962 when riprap was placed along the outer, exposed section of the point. This construction has augmented the natural protection provided by the boulder pavement.

Juniper Point is the middle point on this multiple headland. It is a low hill composed of glacial till and a bedrock core. It extends for 2,200 feet and is lower in elevation than Little Boars Head (Corps of Engineers, 1962). Beach materials here consist of the coarse fraction of the till. Cobbles, shingles and boulders dominate the beach area. Bedrock crops out along the outer end of the point. Other than this natural protection, Juniper Point is unprotected.

Fox Hill Point is the northern 1,050 feet of this headland. It is similar to Juniper Point, but has been protected by riprap that was placed there in 1962 (Corps of Engineers, 1962). Long term changes of the shoreline along this section of the coast have been minimal, due largely to the bedrock control of erosion by waves. Variations in the longshore drifting patterns result in shifting areas of erosion and accretion. The long term net change is erosion, caused by the concentration of energy around this headland. Riprap construction has slowed this natural erosion. This structure in turn has reduced the supply of sand to neighboring beaches.

Environmental Impact

Because of the bedrock control along these headlands, erosion has had a limited effect on the area. Accordingly, the impact of these small changes has been minimal.

BASS BEACH

Assessment of Changes

Bass Beach is a short, small-scale barrier bar which extends 1700 feet north from Fox Hill Point to Rye Ledge (See Map 8, page 59). It fronts Philbrick Pond on its west side. Residential development here is well back from the beach on the landward side of Route 1A and does not interfere with the coastal processes.

Beach material varies from boulders, cobbles, and riprap with a rubble wall on the south, to a shingle ridge on the north with some gravel on the foreshore (Corps of Engineers, 1962). This material has been transported into this pocket beach from the bordering headlands and dumped along the barrier bar by wave generated currents. These same currents continue to shape the beach and have resulted in periodic erosion and accretion. Although Tuttle (1960) states that comparison between photographs taken in 1925 and 1960 show little change in the shoreline, it seems more probable that there has been slight erosion due to lack of material transported into the area.

Erosion has caused some problems with the road bed of Route 1A. Prior to 1948, the bed lay at an elevation of ten feet above sea level. During storms it was continuously overtopped by waves resulting in major damage. This situation was rectified in 1948 when the state raised the roadbed ten feet so that it now rests at 20 feet above sea level (Corps of Engineers, 1962).

The marsh at Bass Beach represents the area of the confluence of several small drainage brooks from North Hampton. Several small brooks, including Chapel Brook, empty into the southwest end of Philbrick Pond, a salt pond at the center of Bass Beach Marsh. Philbrick Pond has an outflow at its southern end and flows to the ocean through a culvert under the old electric railway bed, continuing as a stretch of open water, and then flowing through a culvert under Route 1A. The latter culvert has a floodgate, or clapper valve, employed in previous years.

Environmental Impact

The problem in the marsh is that too much water sits on the marsh surface and does not drain out. Because large areas of the marsh are permanently covered with saline water, the typical marsh plants have died out and dead panne areas

have formed. These dead panne areas are covered by a thick mat of blue/green algae.

It is hard to say in retrospect exactly what the cause of the dead pannes might have been. However, it seems certain that it is related to the mosquito ditches which were dug in the marsh surface, creating high margins along the ditches where the earth was thrown when the ditches were dug. These levees may have trapped water between the ditches and impeded drainage. There is some indication that standing water on the marsh peat causes the peat itself to rot, compact, and subside. That process would tend to speed up the formation of dead pannes. It is also possible that the ditch margins, like dikes, may have simply held the tidal water in the salt hay areas longer than the plants could tolerate and the stress eventually caused the death and decay of the typical high marsh meadow vegetation. Salt marsh plants can tolerate a saltwater bath twice daily, but not a continual soaking in saltwater. Purple loosestrife has not invaded the Bass Beach Marsh because the soil there is too salty and constantly submerged. It exists only along some of the upper margins of the marsh and is not abundant.

The dead panne areas support thriving colonies of blue/green algae and also many insects and, at least in the deeper ones, crustaceans and small fish. The fish and insects attract many shore birds, making Bass Beach one of the best birding marshes along the New Hampshire coast.

Because Bass Beach Marsh is full of birds and free of purple loosestrife, it would be plausible to conclude that the marsh is healthy. This is most definitely not the case. First, Bass Beach Marsh is not a stable ecosystem. The size and extent of the dead pannes has increased rapidly in the past ten years, and without intervention, can be expected to continue to expand. If the process of dead panne formation goes unchecked, the marsh will eventually degrade and become inhospitable to birds and animals. In other words, the current abundance of birds and fish at the Bass Beach marsh represents a step in the gradual decline of the marsh into a stable but non-ecologically productive flooded area. On the beach itself, the only impact of major proportion has been storm damage to the road.

RYE BEACH

Assessment of Changes

The name Rye Beach is a misnomer for the headland which projects between Bass Beach and Jenness Beach (See Map 8, page 59). In actuality it is a bedrock promontory with a mantle of till which has provided material for the beaches to the north and south (Tuttle, 1960).

The bedrock core of the headland drops off at the shoreline, but rises up offshore to form Rye Ledge. The ledge, while consisting of a bedrock core, is littered with many boulders. These boulders are evidence of the erosion of the glacial till which once mantled the ledge.

As a promontory, Rye Beach receives considerable wave action on its shores. The energy of the waves, however, is lessened considerably by the presence of the ledge offshore. Waves approaching from the east are slowed down by the ledge and the associated shallow depths surrounding it.

The material on the point itself is coarse as a result of the wave action. The finer material has been transported by wave generated currents to pocket beaches north and south of the headland. The beach to the south contains shingles, while the beach to the north is slightly finer, made up of sand and gravel (Corps of Engineers, 1962).

The changes which occurred here at Rye Beach are minor. The major change has been erosion of glacial till from the Rye Ledge area and the remaining shoreline. In addition, this eroded material has been redistributed along the bordering shoreline.

Environmental Impact

The impact of these changes to coastal resources has been insignificant.

JENNESS AND CABLE BEACHES

Assessment of Changes

Jenness and Cable Beaches combine to form a 6000 foot barrier bar which has grown south from Straw's Pond and north from Rye Beach (See Map 8, page 59).

It has a sandy foreshore throughout. The backshore materials vary from a shingle ridge at the south to dunes at the north. The barrier has enclosed a salt marsh area called Eel Pond which drains at the north end of Jenness Beach (Corps of Engineers, 1962).

A boulder pavement extends offshore at the center of the beach marking the position of the unconsolidated glacial deposit which has since been eroded away. This deposit has provided much of the fine sand found on the beach at present (Tuttle, 1960). The transport of glacial material into the cove from the adjoining headlands has also contributed to the beach material.

The boulder pavement at the center of the beach has caused a disruption of the normal wave generated currents. By refracting oncoming waves the pavement starts currents flowing north and south. The resultant currents are variable and largely dependent on the angle of incidence of the oncoming waves.

Eel Pond is located behind the beach. At some point in the past, over fifty years ago, Eel Pond Marsh was tidally influenced. It is now a freshwater system (Richardson, 1986). A combination of highway construction and natural longshore drift caused the outlet to close. This necessitated the construction of a culvert to drain the pond in order to prevent flooding of the surrounding inland areas. This consists of one long pipe, protected by riprap, whose outlet is offshore. It is possible that, occasionally, some salt water travels up the pipe on the flood tide, but Eel Pond is merely a collector of inland fresh water with an outlet to the ocean.

Environmental Impact

The change from an estuary to a fresh water marsh has not had a detrimental effect on Eel Pond Marsh. The area, largely a rush meadow, has been, for many years, a stable healthy system. As an important habitat for wildlife, it is full of water fowl and muskrat. There is no perceived need to alter the system by reinstating the saltwater influence. (Ibid)

STRAWS POINT

Assessment of Changes

Straws Point is the headland which borders Cable Beach to the north. It stretches 2500 feet north to Varrel's Point which is an extension of the same headland (See Maps 8 and 9, pages 59 and 67). Straws Point is composed of a bedrock core with a mantle of till (Goldthwait, 1951). It is a low headland and has experienced extensive erosion.

Evidence of this erosion is obvious to the observer. At the time when the large summer estates were built, during the post-civil war era, a loop road was built around the point to facilitate the turning around of carriages. Until ten years ago this road was still used by residents of the point (Rye Conservation Commission, 1977). However, in the last ten years, wave erosion has undercut the entire outer loop, which has subsequently fallen into the sea. In addition to this erosion, there is a large boulder pavement, particularly at the south end of the point which delineates the original extent of the headland. Tuttle (1960) estimates, from the extent of the boulder pavement, erosion of 50 to 100 feet at the seaward edge.

Environmental Impact

The changes at Straws Point have been erosional in nature and the major impact has been to the recreational and aesthetic resources of the point. The erosion has limited the use of the shore for bathing, and undermined the outer loop road, making it unusable. In addition, the riprap placed along the outer periphery of the point to control erosion has decreased the aesthetic value of the point.

VARREL'S POINT

Assessment of Changes

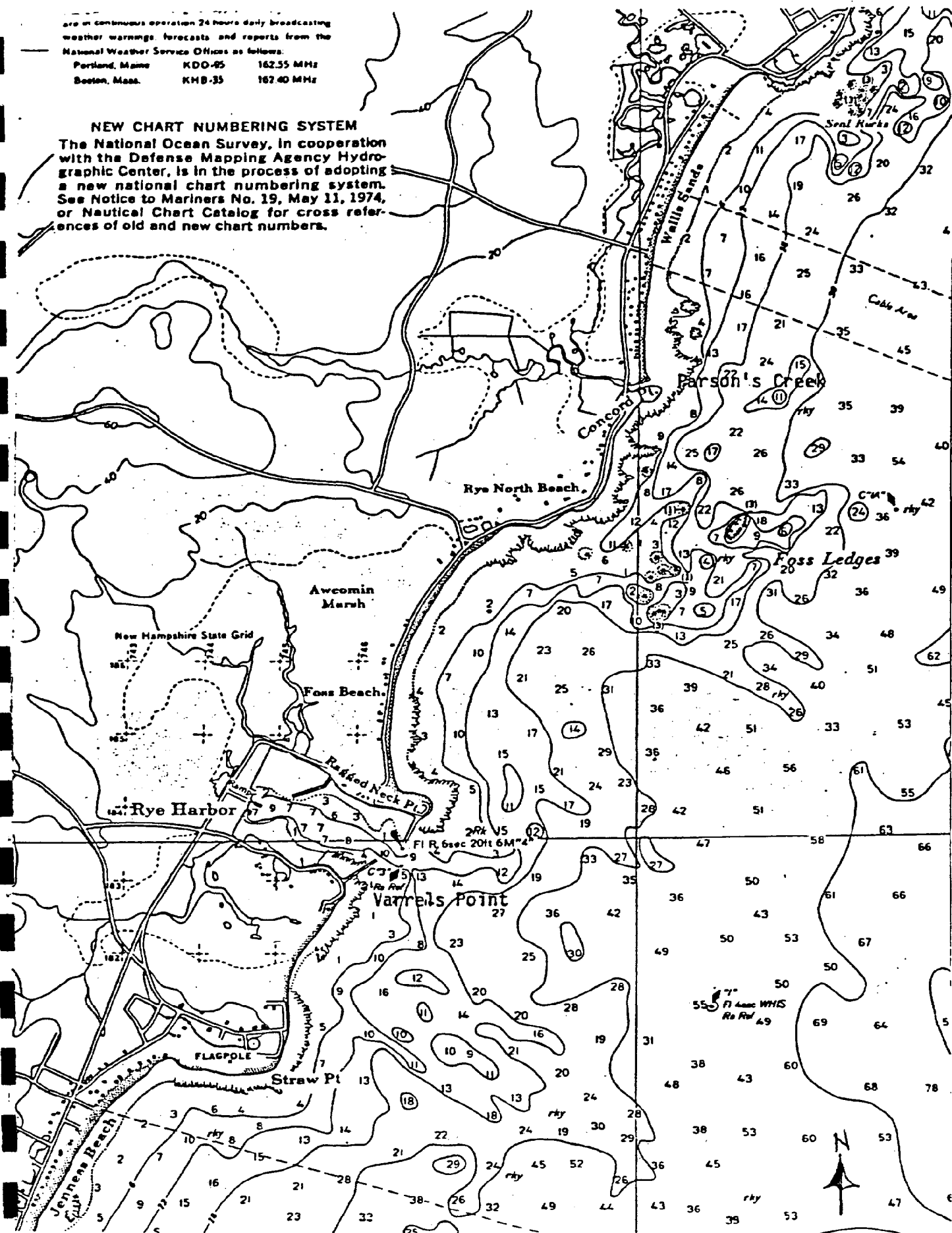
Varrel's Point is a northern extension of the Straws Point headland. It stretches 2000 feet north from Straws Point to Rye Harbor (See Maps 8 and 9, pages 59 and 67). It is a barrier bar built of coarse material north from Straws Point. The backshore material varies from a shingle ridge at the south to dunes at the north (Corps of Engineers, 1962).

are in continuous operation 24 hours daily broadcasting weather warnings, forecasts and reports from the National Weather Service Offices as follows:

Portland, Maine KDO-45 162.55 MHz
Boston, Mass. KHB-35 167.40 MHz

NEW CHART NUMBERING SYSTEM

The National Ocean Survey, in cooperation with the Defense Mapping Agency Hydrographic Center, is in the process of adopting a new national chart numbering system. See Notice to Mariners No. 19, May 11, 1974, or Nautical Chart Catalog for cross references of old and new chart numbers.



SOURCE: USC&GS Chart #211

MAP 9

The barrier bar grew predominantly from the south, but received material from the north and south. There are large boulder pavements to the north at Ragged Neck off the point itself and to the south at Straws Point (Tuttle, 1960). A salt marsh lies to the west of this barrier bar. This marsh experiences tidal influence through its outlet into Rye Harbor, and receives all of its protection from the Varrel's Point barrier. The boulder pavement at Varrel's Point indicates the presence of a till body here at some point in the past (Tuttle, 1960). This glacial deposit has been eroded totally, as the material which composes Varrel's Point has all been reworked and sorted by wave action.

At the north end, the dunes have been extensively developed creating a need for protection from storm waves. Huge blocks of rock have been placed on the shore along this section. They stand at least five feet over the road bed and adjoin the south jetty at Rye Harbor.

Environmental Impact

Major erosion has caused an adverse impact on the recreational, aesthetic, and economic resources of area. As a barrier bar, the point once had a sandy beach suitable for swimming and sunbathing. However, when the houses were constructed on the dunes, the protective stone had to be placed where the beach once was. The riprap was placed at great expense in both money and loss of beach area. In addition, it has blocked off the view from most of the houses on the point. While serving a necessary protective role, the riprap has also detrimentally affected the scenic nature of the point.

RYE HARBOR

Assessment of Changes

Rye Harbor lies between Varrel's Point on the south and Ragged Neck on the north (See Map ^{page 63} 9.8). It provides moorings for many boats. The points protect large salt marshes -- Awcomin Marsh to the north and an unnamed marsh to the south, which drain into the harbor. They are flushed by tides and supply considerable sediment which is carried out into the harbor by tidal currents. Some of this sediment is carried out of the harbor and distributed there by longshore currents. Some of the sediment is deposited in the harbor, necessitating periodic dredging. The harbor was open to the sea until 1939-1941 when two protective jetties were built. (Corps of Engineers, 1962)

The configuration of the jetties has exposed the north shore of the harbor to southeast swells. Not only are the jetties open to the southeast, but their layout actually channels these swells into the harbor. During the period from 1944-1957 the north shore of Rye Harbor receded 50 to 75 feet (Corps of Engineers, 1962). Riprap placed along the critical erosion area has slowed the erosion at that point, but storm waves still overtop the bank and deposit debris on lawns fronting the harbor.

There is an inner jetty constructed to protect the channel draining Awcomin Marsh (Sullivan, 1977). This protection became necessary due to the erosive effect of the southeast swells which enter the harbor. The construction plan also included a dredging operation behind the jetty to expand the mooring capacity of the harbor. This part of the operation was cancelled, and the dredging never took place. At present, there exists behind this jetty a large mud flat which is exposed at low tide.

Prior to the construction of the jetty, this sedimentation occurred during ebb tidal action as sediment-laden water flowed out of Awcomin Marsh. As the tidal current spread out and slowed down in the harbor, suspended material settled out and fell to the bottom. Post-construction sedimentation has been aided by the presence of the jetty which acts as a trap for the outgoing, sediment-laden water from Awcomin Marsh.

Environmental Impact

The erosion and accretion which have occurred in Rye Harbor have had various impacts on the resources of the area. Foremost is the economic and aesthetic impact of the erosion on the north shore of the harbor. The massive erosion here has caused considerable loss of land and large monetary expenditures for protective riprap. In addition, the erosion has detracted from the natural beauty of the area, both through the loss of land and the unsightliness of the riprap.

The naturally occurring sedimentation has affected the recreational use as well as the ecology and the economy of the harbor. As the sand builds up in the harbor, it interferes with boating use. The channels become too shallow, necessitating periodic dredging. The accretion also has an affect on the economy of the region by limiting further the mooring capacity of this already small harbor. An additional burden on the economy is the large cost of dredging out the harbor.

However, the major impact is a result of the dredging which becomes necessary due to accretion within the harbor. The impact is much the same as the impact of dredging in Hampton Harbor. The dredging itself causes destruction of organisms in the dredged material while the sediment churned up in the process settles out and smothers other organisms. This is of particular concern because of the large clam and oyster beds in the harbor.

The clam beds in the harbor are located behind the inner jetty and in the south marsh behind Varrel's Point. The clam beds in the marsh are less vulnerable than the bed behind the jetty due to the protection afforded by the narrow inlet, and the limited time when water is flowing into the marsh. However, the jetty clam bed is highly susceptible to damage from dredging, as well as from harbor pollution.

RYE HARBOR STATE PARK

Assessment of Changes

Rye Harbor State Park occupies the point known as Ragged Neck, adjacent to Rye Harbor (See Map 9, page 67). On its outer shore is natural riprap from Foss Beach to the harbor jetty. There is a large boulder pavement offshore which

helps decrease the erosive capabilities of oncoming waves (Tuttle, 1960). On the protected side of the jetty there lies a small area of sand.

The point was once much larger, as indicated by the boulder pavement offshore. Tuttle points out that there is no bedrock core here. The protruding nature of the point is due entirely to the orientation of the glacial deposit, not to resistance offered by bedrock (Tuttle, 1960).

Environmental Impact

Erosion of the outer extent of the neck incurred the need for protection from the storm waves. The protective riprap which was emplaced has had an adverse effect on the recreational use of the park. Swimming was once possible from all points on the neck, but following the placement of the riprap the only swimming area is the sand beach inside the harbor jetty.

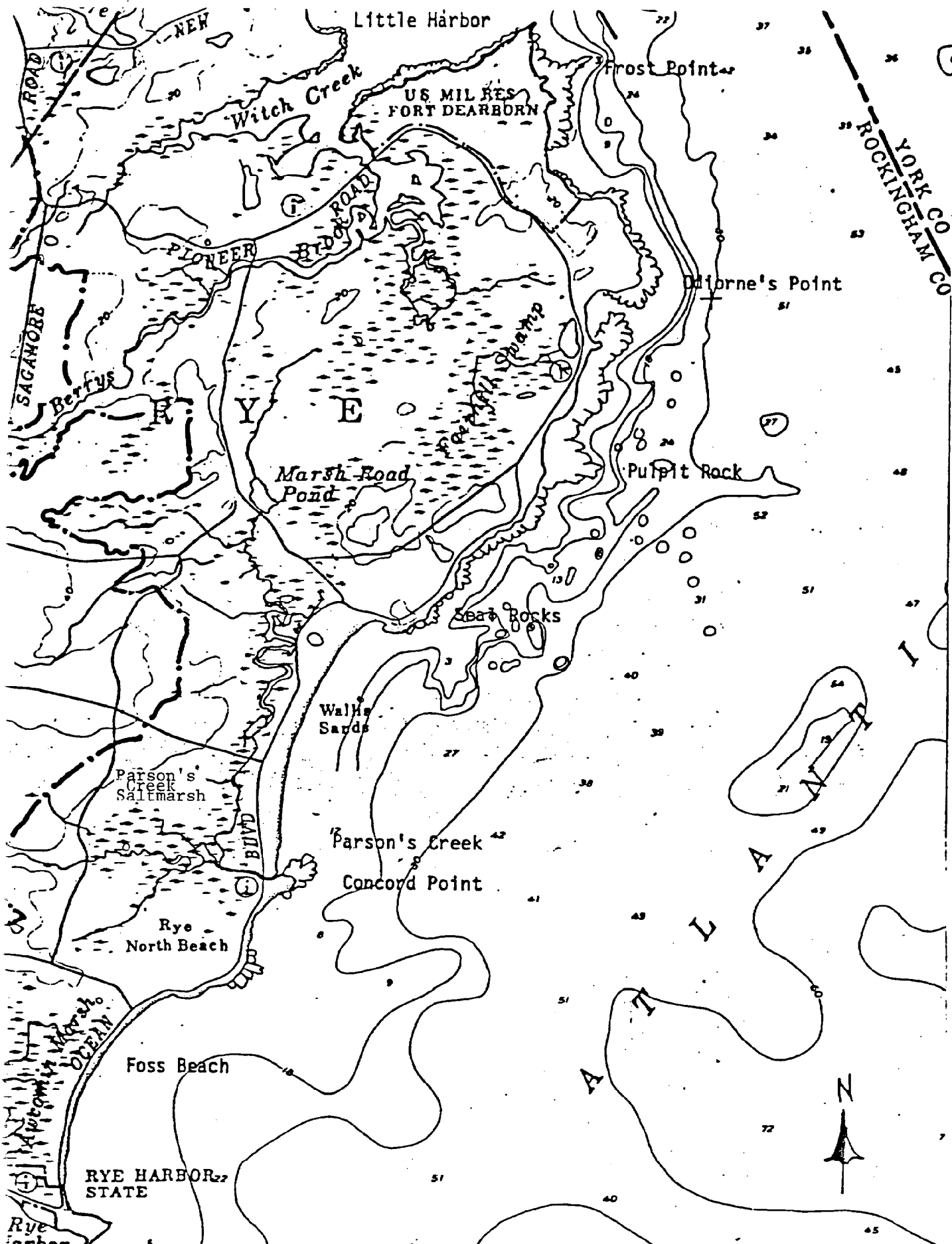
Immediately offshore from the jetty extending south into Rye Harbor there lies a major clam flat (See Map 5, page 39). This clam flat is exposed to the sea and hence receives regular reworking during each northeast storm.

Erosion at Ragged Neck has occurred on a regular basis, depending for the most part on the severity of winter storms. The changes year to year have been small, but the aggregate result has been recession of the point. The northeast storm of February 1972 caused major erosion at the point by overtopping the riprap and scouring behind the structure. The Blizzard of 1978 certainly caused extensive damage to the area. Along North Beach in Hampton, Little Boar's Head District in North Hampton, and the Rye Beach area, storm surge displaced thousands of yards of sand, broke up granite groins, and damaged steel and reinforced concrete bulkheads which protected roads and dwellings. Private dwellings and property were damaged in North Hampton and Rye by surf surge with some dwellings being completely lifted from their foundations.

FOSS BEACH

Assessment of Changes

Foss Beach is a barrier bar which has grown southward from Rye North Beach to Ragged Neck. It encloses and protects Awcomin Marsh which drains into Rye Harbor (See Map 9 and 10, pages 67 and 72). The overall length of Foss Beach is 4000 feet (Corps of Engineers, 1977).



SOURCE: USGS Kittery, Me.-N.H. Quadrangle

MAP 10

The beach structure is different from most other beaches in the region. The sole protection provided by the beach is a tall shingle ridge between Route 1A and the water. This ridge is composed of rounded stone and stands 25 feet above sea level.

Comparison between Corps of Engineers (1962) photographs and present conditions shows gradual erosion. A stone wall built and maintained by the Department of Public Works and Highways, visible in the 1962 photograph, has been almost entirely covered by the receding ridge. The shape of the ridge has changed from a gentle slope to a steep mound. This can be explained by the erosion process at work here. Storm waves push the mound landward, spreading shingles over the highway and the marsh on the western side of the highway. The highway department then clears the road by piling the rocks back onto the unstable mound visible today.

This stabilization is made necessary by the presence of the highway on the leeward side of the ridge, as well as the various houses and restaurants situated across the road from the ridge. The human interest requires stabilization of the natural processes -- recession and breaching. This stabilization affects the energy dissipation of storm waves breaking on the beach in the following manner: storm waves breaking on a wide beach are usually dissipated before they reach the dunes. However, on a narrow beach such as North or Foss Beaches, the waves break directly on the narrow beach and shingle barrier. The tremendous release of energy in a very short distance results in two modifications of the area. First, the ridge is topped or even breached by the attack of the waves. Second, this concentrated release of energy in the beach area carries away all the sand size grains, leaving only that fraction of the beach material which cannot be moved.

Material used in the formation of the barrier bar has come from various sources. Wave energy concentrated on the headlands has eroded finer material and transported it into the cove where the less turbulent waters allowed the sand to drop. Continual modification by wave-generated currents resulted in the growth of the bar. In addition, several offshore glacial deposits have been reworked by waves, and the finer material has been moved onshore to the beach area (Tuttle, 1960). Once these offshore deposits were removed, oncoming waves could approach the center of the beach unimpaired. The impact of waves breaking on the beach area adjacent to the headlands is reduced by refraction. However, at the center of the beach, these unimpaired waves break directly on the shore.

The result is the formation of a slightly higher shingle ridge at mid-beach, as the larger waves run up further and transport shingles higher on the protective ridge (Lewis, et.al., 1931 from Tuttle, 1960). The cycle has gone from one of deposition of reworked offshore glacial material, to erosion, once the protective offshore deposits were depleted.

Environmental Impact

The erosion of Foss Beach has had a negative effect on the recreational use of the beach and has imperiled the state highway located behind the shingle ridge. As at North Beach in Hampton, Foss Beach has suffered extreme erosion in the form of retreat of the shoreline, steepening of the beach face, and a change in beach material to much coarser shingles. The end result is, as at North Beach, an unusable beach, which is compounded by the presence of a protective steep shingle ridge. This ridge must be scaled in order to gain access to the beach and, due to its steepness, this is a difficult task.

This ridge, while performing an important protective function, also has an adverse aesthetic impact. It effectively blocks the view of the ocean not only from the road, but from the first floor of the houses bordering Route 1A on the west.

The erosive effect of the storm waves is to topple the ridge onto the road. Large expenditures of funds are required to clean up the shingles and reconstruct the ridge. However, the poor condition of the beach does not have a significant economic impact because Foss Beach is primarily used by town residents and guests of the motels in the area. There is no public parking facility adjacent to the beach. Out-of-town visitors therefore tend to use Wallis Sands or Jenness Beaches, where parking is available.

RYE NORTH BEACH

Assessment of Change

Rye North Beach is a headland which abuts Foss Beach on the north. It extends half a mile north to Concord Point (See Map 9 and 10, pages 67 and 72). Its shore consists of bedrock, covered with coarse material. Due to the bedrock control of erosion, there has been very little recession of the shoreline.

The glacial deposit which mantles the bedrock core of Rye North Beach once extended further out into the sea. There is an extensive boulder pavement off the southeast end of the point (Tuttle, 1960). This glacial deposit provided much beach material for Foss Beach as it was eroded by the sea. However, now that the bedrock core has been exposed, the headland resists the wave attack and very little new material is liberated. This decrease in the supply of sand has been one of the major causes of decrease in beach width at Foss Beach.

Environmental Impact

The impact of shoreline change at Rye North Beach has been negligible due to the minimal amount of erosion.

CONCORD POINT

Assessment of Changes

Concord Point is a northern continuation of the Rye North Beach headland (See Map 10, page 72). It stretches 1000 feet from its northern point north to Wallis Sands Beach. Its shore is a continuous outcropping of bedrock which is covered with large boulders. Erosion is not a concern here because of the resistance of the bedrock to erosion.

Parson's Creek running between the north edge of Concord Point and the southern end of Wallis Sands Beach, drains the saltmarsh which is located to the north behind Wallis Sands Beach. "A combination of manmade and natural events over an extended period of time have contributed to the marsh's present condition. . . . Degradation has resulted from an insidious process of small impacts over long periods of time". (Simpson, 1986) A significant portion of the original high marsh system behind Wallis Sands Beach is showing signs of degradation. The several factors which have impeded tidal inundation and led to the degradation of the marsh are discussed below:

-Remains of a barge which came ashore several years ago have become imbedded in the sand and gravel which was carried to the mouth of Parson's Creek by long-shore drift and storm surges. Because the wave action on the beach north of the creek is counter clockwise, the barge caused the formation of a sand bar at the mouth of the creek. As a result, sedimentation in the creek has increased, blocking tidal wave action; interfering with migration of ocean species

into and out of the marsh; inhibiting the flushing of seaweed and other debris which periodically gets brought in by storms. If covered with sediment, this trapped algae quickly becomes anaerobic and gives off noxious gases. These offensive fumes have, in the past, discolored painted surfaces on nearby houses and a newly painted highway bridge; caused nausea, sore throats, headaches and other ailments among the residents (Simpson, 1986).

-The bridge on Old Wallis Road which once spanned the creek has decayed, and the stone abutments have fallen into the channel, damming the creek.

-Under New Wallis Road, Parson's Creek is very shallow. Debris, cement blocks, rocks, etc. can be seen in the waters 15 to 20 feet on either side of the bridge and under it (Simpson, 1986). The shallow depth and the accumulation of sediment and debris have contributed to the lack of flushing higher up in the marsh.

-The owner of the property on the creek between the Red Roof Market and the horse paddock has attempted to stabilize the bank with an assortment of metal, wood, and discarded household items all held together with rope and cable. This debris frequently falls into the creek and either gets caught on the shallows to the south, or stuck in the narrow stream channel that surrounds the horse paddock to the north. Thus, the debris further impedes tidal flushing. In addition, if this debris floats into the marsh at high tide, it could destroy saltmarsh vegetation and create pannes. (Simpson, 1986)

-Since 1970, progressive amounts of fill have been dumped on the marsh at the horse paddock. In 1971, a fence and small barn were erected on this filled area (Simpson, 1986).

-In 1963, Route 1A (Ocean Boulevard) was rerouted to improve the State Facility at Wallis Sands State Beach. This new section of road was built over salt marsh, separating a section of marsh from its main drainage system. Although culverts were placed under Route 1A to connect this separated section of marsh with the creek area, these culverts became blocked over time. Without the benefit of incoming tides, the salt pond on the east side of 1-A slowly developed into a brackish water system (Simpson, 1986).

-Extreme flooding took place in 1978 and 1979 and inundated Wallis and Marsh

Roads. During these and other previous storms, sand and debris were deposited in Parson's Creek and on the marsh (Simpson, 1986).

-Winter snow storms have an indirect impact on the marsh: snow and sand find their way onto the marsh when the roads are plowed. An accumulation of this sand is not only detrimental to the marsh vegetation, but also increases the elevation of the marsh along the roadsides. When this happens, border vegetation supercedes tidal marsh species (Simpson, 1986).

Parson's Creek Marsh has suffered directly from both the dumping of fill onto the marsh and isolation from tidal flow, due to the rerouting of 1A. Other impacts are not so obvious. Blockages occur along the length of the creek, reducing the tidal ebb and flow. There is evidence of organics from leaking septic systems and the horse paddock. Finally, there are periodic effects from coastal storms. No single identified site can be pointed to as causing the degeneration of Parson's Creek Marsh. The impact is cumulative. Man's abuse of the marsh has been gradual, and the resultant negative effects have taken many years to be realized (Simpson, 1986).

Environmental Impact

Several factors have combined to reduce the frequency and distance of tidal inundation into the marsh. Flushing of sediment and organic debris from the upper reaches of the marsh is inhibited. The migration of ocean species in and out of the marsh is restricted. Surface turf has decayed because of poor drainage.

The blockage at Wallis Road and Old Wallis Road have been removed and a channel has been dredged at Concord Point. The tidal flow to the upper reaches of the marsh has been improved and the sedimentation problems at the mouth of the creek have been ameliorated temporarily. The enhanced flushing has helped to bring oxygen and saltwater to the far reaches of the marsh, to rid the marsh channels of sediments, and to promote revegetation by peat producing plants, reducing mosquito populations. The flow to the upper reaches has been improved, but the degraded marsh has not been restored to its former health (Simpson, 1986).

WALLIS SANDS BEACH

Assessment of Changes

Wallis Sands Beach is a wide sand beach extending one mile north from Concord Point to Seal Rocks (See Map 9 and 10, pages 67 and 72). The slope of the beach, both on and offshore is very gentle. At low tide, sand flats extend 250 to 450 feet offshore.

The dunes behind the beach have been developed with residential structures. Some of the houses are built directly on the peak of dunes, while others sit on the protected side. Most of the landowners have undertaken protection on their own, resulting in a variety of piecemeal protective devices: bulkheads, seawalls, and riprap protective devices are in use, but no continuous system of protection exists.

At the north end of the beach lies Wallis Sands State Beach. At the state beach there are no dunes now, only a large parking area where the dunes once were. The state beach extends from the bedrock at Seal Rocks to a groin constructed at the south end of the beach. The groin appears to have very little effect on the longshore transport in the area. It was constructed shortly after the state took over the operation of the beach and placed a large volume of artificial fill there in 1973. (Brown, 1977)

There is some movement of sand along the beach as evidenced by the periodic closing of Parson's Creek which drains the saltmarsh behind this barrier bar. It is doubtful that much material is carried around either of the bordering headlands. Sand is transported within the cove south and north but also on and offshore. When carried offshore by steep erosive waves, sand is placed on one of the offshore bars. Movement back onto the beach usually follows the return of more gentle wave action.

Wallis Sands Beach is a prime example of a functioning barrier beach system on the New Hampshire coastline. Although the dunes have been built upon and protected, the protection is not a continuous wall. These dunes can still perform many of the functions of a foredune. They provide the last line of defense on the beach against storm waves, acting as a flexible barrier with the ability to dissipate energy, not concentrate and reflect it.

Another important aspect of the Wallis Sands Beach system is offshore topography. The gently sloping beach on and offshore, in conjunction with the offshore bars, dissipates the energy of the waves as they approach the beach. By the time a wave actually hits the beach, its energy level is much less than if it had broken directly on the beach. This is due to the drag placed on the wave by the shallow, sandy bottom.

Environmental Impact

As noted in the assessment of change at Wallis Sands Beach, the beach has remained relatively stable while retreating very gradually. The short-term changes which have occurred have been small in nature and have had no severe impact on the resources of the area.

However, winter storms, such as the February 1978 storm, do cause damage to the houses built on the dunes, especially those on the peaks of the lower dunes. Waves overtopped the various protective devices and broke directly on the dunes and the houses built upon them. This storm caused substantial erosion as well as structural damage due to undercutting.

Nonetheless, all the small changes which occur regularly, while not constituting an immediate problem, add up over the long run. The long-term results of the erosion will include the destruction of the houses upon the dunes as well as the recession of the dunes. It should be emphasized that the results are long term, and that at present the beach and dunes receive adequate protection from the gently sloping ocean floor.

SEAL ROCKS AND PULPIT ROCK

Assessment of Changes

The headland which stretches from Wallis Sands Beach to Odiorne's Point is marked by two promontories, Seal Rocks and Pulpit Rock (See Map 10, page 72). The area is primarily bedrock, with several small pockets at the northern end.

Recent erosion is minimal because of the bedrock control of the shoreline. Previous erosion of glacial deposits provided some material for Wallis Sands to the south, and left large boulder pavements off these various headlands.

Along this expanse of shore, the bedrock drops off in a short cliff to the beach which consists of large boulders and cobbles. Bedrock crops out offshore in the form of ledges which are also littered by large boulders. These boulders are either glacial erratics or plucked from the bedrock by wave action. Erosion is a slow process on a bedrock headland, but accretion can occur rapidly. There has been an accumulation of finer-grained material in the quieter coves between headlands. This material probably originated as glacial deposits, and has been redistributed by the sea. There is little transfer of material between coves along this section of the coast due to the prominence of the headlands. Most wave-generated currents move into the coves from the bordering headlands. Any actual transfer of beach material is on and offshore, and seasonal in nature.

North of Pulpit Rock lies the back edge of Fairhill Swamp which drains into Little Harbor to the north. Periodic breaching by storm waves used to occur here. Sometimes the inlet would remain open after the storm and allow some of the marsh water to exit through the temporary inlet (Brown, 1977).

However, large boulders were placed along this stretch to protect the road. These boulders have limited the periodic breaching by major storms, and have provided effective protection from waves of less intense storms.

Environmental Impact

The changes to the shoreline are minimal because the shoreline has remained so stable. However, the large rocks placed north of Pulpit Rock have had an impact on the ecology of the saltmarsh and the aesthetic value of the shore.

The extent of erosion is evident at Odiorne's Point. First, submerged stumps are visible at low tide. These stumps are a vestige of a forest which grew when sea level was lower than at present. With encroachment of the sea upon the land, the sea killed and felled the trees, leaving the stumps which are present today. Sand then buried the stumps until recent unearthing has made them visible again (Goldthwait, 1951).

Second, the barrier bar located south of the point has receded gradually onto the marsh behind it. For this reason, the marsh is now smaller than it was. The migration of the bar shoreward has caused some damage to the road which runs along the western edge of the bar. However, relocation of the road has not yet become necessary.

Third, a life boat house and launching dock which sat on the barrier bar south of the point has been totally destroyed by erosion. The structure did remain intact until the 1940's, when a series of storms destroyed in succession the dock, the pilings, and finally the house itself. Today not even the foundation remains. During the past 30 years the shore of the barrier bar in the cove has receded nearly 150 feet (Brown, 1977).

While there may be various causes for this erosion, such as lowering of the sand supply rate and lack of bedrock resistance, the most prominent reason must be the northeast orientation of the cove. Although oncoming waves are refracted by the bordering headlands, the cove still bears the direct attack of northeast storms.

The decrease in the rate of sand supply has affected the size of the beach material. As the waves cut into the glacial till on the headlands, fine material was liberated, some of which was deposited on the pocket beach. As the bedrock was exposed, less and less fine material was liberated. There was, in fact, a fine sand beach in this pocket which was very popular for swimming (Brown, 1977).

Ecologically, the rocks have affected the marsh by not allowing breaching to occur. Periodic breaching is beneficial for the marsh because it adds fresh sea water to the marsh water. This water contains various nutrients which can be used by the organisms of the marsh. In addition, the excess water helps flush stagnant water out of the upper reaches of the marsh through Little Harbor. The boulders have eliminated all these effects of breaching which are beneficial to the marsh.

The large boulders have affected the scenic nature of the area: They have covered a scenic beach area making it unattractive to viewers, and they have eliminated the view of the sea once afforded from the road. Now one must park and climb over the large boulders to view the ocean.

ODIORNE'S POINT

Assessment of Changes

Odiorne's Point is a state park facing northeast extending from a small pocket beach north to Fort Deerborn on Frost Point (See Map 10, page 72). The point itself is composed of bedrock with a mantle of till (Goldthwait, 1951). There is a small hill in the center of the point, but the point itself is rather low. Erosion on the point is not a problem because the bedrock affords protection from storm waves.

However, the pocket to the south of the point has been shaped and affected by storm activity. At present the beach is composed predominantly of shingles in addition to a shingle ridge behind the beach. Behind the beach is a lagoon area which derives its protection from the barrier beach.

Environmental Impact

The major impact of change at Odiorne's Point has been on the recreational use of the state park. The major recession in the cove has diminished the amount of land area in the park and hence limited its use. In addition, the loss of sand has eliminated the beach from use for swimming or sunbathing.

The destruction of the boat house by storm waves affects the historical nature of the point. Although unused at its demise, the structure provided some insight into life-saving history prior to the advent of motorized craft.

ODIORNE'S POINT TO FROST POINT

Assessment of Changes

This expanse of shoreline consists of a pocket beach adjacent to Odiorne's Point, several pockets on Frost Point, and Frost Point itself (See Map 6, page 42). There is much exposed bedrock, and beach material is accordingly coarse, ranging from gravel to boulders.

The north pocket adjacent to Odiorne's Point is backed by a wave-cut scarp. The scarp is cut into glacial till and has receded in the past 30 years until it was recently stabilized by riprap (Brown, 1977). This erosion has provided any sand found on the beach.

Wave erosion of the bedrock is more evident in this northern area than elsewhere along the coast. The bedrock is more brittle than the bedrock further south and has many more fracture joints (Tuttle, 1960). These fracture joints facilitate wave erosion and also frost-aided erosion. During the winter, water drawn into the joint expands when it freezes, quarrying the rock free.

Generally, the changes along this section of shore have been minimal. Although this bedrock is more prone to erosion, it still resists the attack of the sea well. The only major change has been the erosion of the glacial material north of Odiorne's Point.

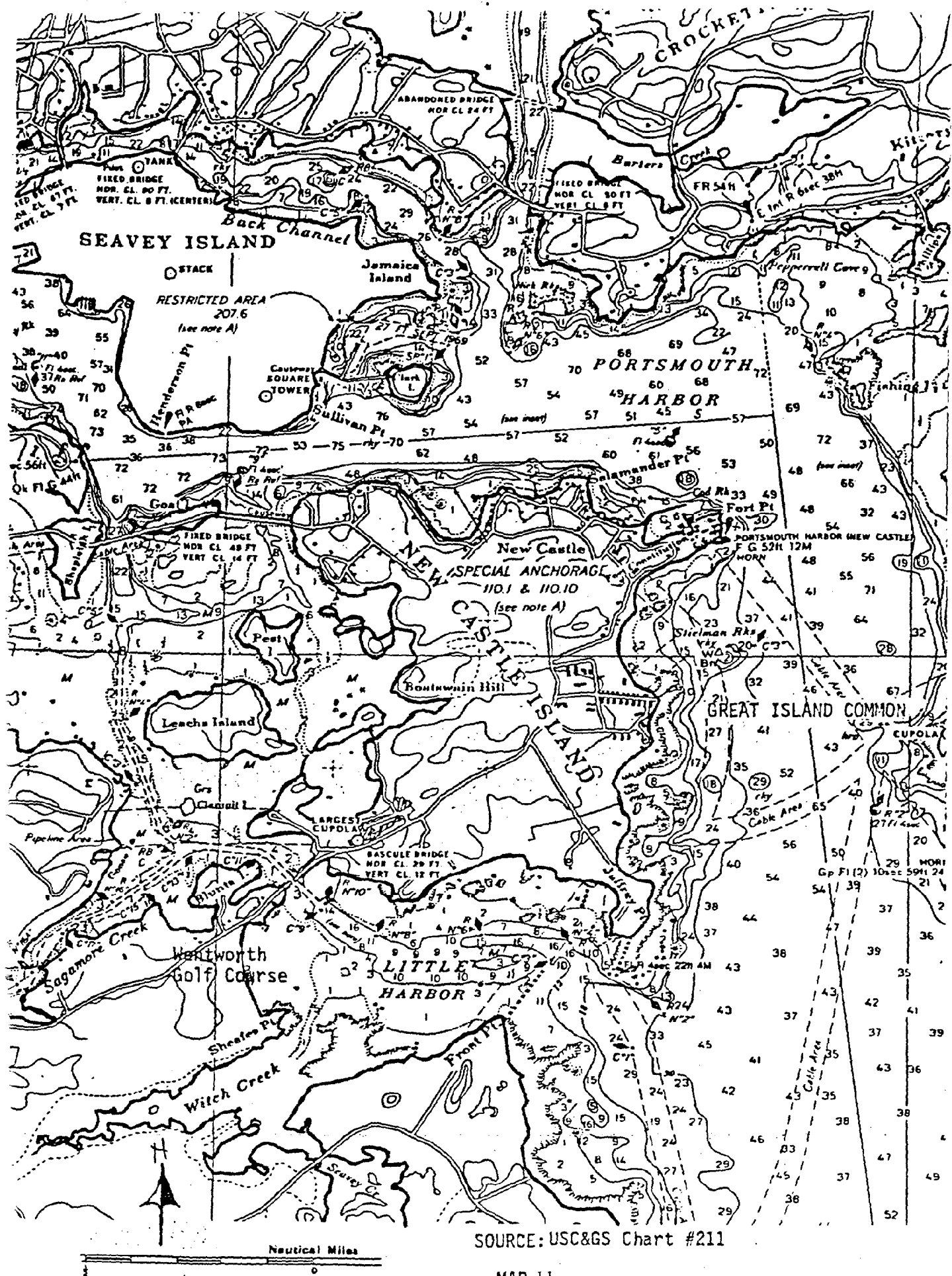
Environmental Impact

By virtue of the limited change which has taken place in this area, the impact on the resources has been minimal.

LITTLE HARBOR

Assessment of Changes

Little Harbor is the body of water which is bounded by Frost Point, Rye on the south and southeast and Jaffrey Point, Newcastle on the north and northeast (See Map 11, page 84). The harbor receives much natural protection, as well as supplementary constructed protection. Frost Point and Jaffrey Point provide



natural protection from all directions, with the exception of due east. Prior to jetty construction, swells from the east could enter the harbor unimpeded and cause damage to moored boats and the shoreline itself.

Jetties were constructed to protect the harbor, but due to their exposure to the forces of the sea, there was a tendency for them to break down. The Frost Point jetty proved more susceptible to damage from the February 1972 northeast storm, and subsequently the waves displaced many blocks from the jetty. The jetty was repaired by the Corps of Engineers during the summer of 1972.

Environmental Impact

The easterly storm swells which sometimes enter the harbor also damage a large clam flat situated on the nearshore area adjacent to the golf course as shown on Map 11. This extensive clam flat is of recreational importance and the damage incurred has affected this usage. As the storm waves enter the harbor, they rework bottom sediments in a shallow area prior to breaching adjacent to the golf course. These waves move sand back and forth over the flats stripping material from some areas and redistributing it over the other areas of the flats. Clams in regions which lost sand are exposed to the cold sea water. This is especially harmful to seed clams which are much more susceptible to damage than adult clams. Seed clams at sites of deposition also run the risk of suffocation under the redeposited material. The overall effect of the shifting of material is a decrease in the number of clams in the flats, specifically the seed clams. This affects the population for several years following.

NEWCASTLE

Assessment of Changes

Newcastle's eastern shore is irregular in form, varying from bedrock headlands to unconsolidated pocket beaches (See Map 11, page 84). The predominant coastal process has been that of wave-generated currents transporting material from the headlands into the pockets. While the mantle of glacial material still existed, the procession of material from the headlands to the coves were relatively constant. However, once the mantle was worn away and waves broke on the resistant bedrock, the rate of sediment supply dropped off considerably. Although the bedrock here is more susceptible to erosion than the bedrock further

south, the process is still very slow and no appreciable changes have occurred in the bedrock (Tuttle, 1960).

Jaffrey Point is the southernmost point in Newcastle. It is composed of bedrock with a thin mantle of till which is no longer in reach of wave runup. Since the waves carried away the last of the exposed glacial material, the point has remained somewhat stable, although the Corps of Engineers (1962) reports that the area north and east of the jetty had receded up to 50 feet between 1898 and 1953.

The cove north of Jaffrey Point, Fort Stark is a different matter. Material from the headlands were deposited here, but as the supply diminished, so did the deposition rate. Coarse beach materials, shingles, cobbles, and a shingle ridge in the backshore are present in this pocket. There has been considerable storm damage due to wave runup on the shore (Corps of Engineers, 1962).

There is an erosion problem, particularly east of Battery Hays. Both the steep path and the retaining wall are eroding due to ocean wave action. There is also evidence of erosion caused by wave action at the Little Harbor end of Fort Stark by Battery Lytle. Other evidence of the erosion is shown in the dislodging and tilting of the three inch salute gun and the undermining of an adjacent concrete platform. These two areas of erosion were probably caused by wind driven storms from the northeast and southwest.

The middle point on the eastern Newcastle shore is Great Island Common, a former military base. The Great Island Common is a bedrock point which grants protection to the structures built constructed at the site. The mantle of glacial material, present on most headlands in the region, is still under wave attack on the south side of the Common, where there is a low receding bluff of unconsolidated material (Corps of Engineers, 1962).

The cove north of Great Island Common has been experiencing erosion along its southern extent. The beach material consists of fine sand on the foreshore, sand dunes on the southern backshore, and a sand and shingle ridge on the northern backshore. This beach is owned by the town and used as a public bathing beach.

The constant erosion of the shoreline at Great Island Common and the town cemetery over the last years has resulted in the loss of approximately 16 to 19 feet of land.

The northernmost point which is occupied by the Coast Guard and the State Division of Parks and Recreation is Fort Constitution. This headland is bedrock and has proven very stable over time.

Environmental Impact

The erosion at Great Island Common has incurred economic and social costs: in the fall of 1985, rip rap was installed to prevent further erosion. This is a prime area, close to the beach, used for picnicking and also by senior citizens to enjoy the view of the beach and harbor. The problems at Fort Stark have similar effects and will eventually have to be rectified.

However, due to the resistance of bedrock to wave action along most of the Newcastle shore, these are the only changes. Therefore, there has been relatively little impact on the resources of the area.

ISLES OF SHOALS

Assessment of Changes

The Isles of Shoals lie seven miles off the coast of New Hampshire (See Map 12, page 88). They are divided by the Maine-New Hampshire state boundary, with Star Island, Lunging Island, and White Island located in New Hampshire. These are small islands. The largest in New Hampshire, Star Island, is .5 miles long.

These islands are extremely exposed to the sea and have been eroded extensively by wave action and sea level rise. This erosion has been most pronounced on the east-facing shores because wave attack is much more active on this side. Extensive jointing in the bedrock aids erosion by facilitating removal of quarried pieces of rock. Freezing water also helps loosen parts of the bedrock cliffs (Fowler-Billings, 1959). Star Island is the largest and farthest east of the New Hampshire islands. It is the most exposed and has experienced the greatest erosion. Records of shoreline change on the isles are less extensive than mainland records due to the lack of settlement. The cliffs on the eastern



Source: U.S.G.S. ISLES OF SHOALS Quadrangle, 1956

MAP 12

side bear evidence of the erosion which has taken place, though no quantitative records exist.

White Island lies .75 miles southwest of Star Island and is much smaller. It is longer in the east-west direction and therefore is attacked most effectively by south and southeast storms. This wave attack has eroded the south and east shores of the island. Eroded material, of both glacial and bedrock origin, has been transported west to form a bar connecting White Island and Seavey's Island. This connecting bar, is covered at high tide and is composed of coarse cobbles and boulders (Fowler-Billings, 1959).

Lunging Island is the smallest of the three islands in New Hampshire and is located .5 miles west of Star Island. It receives protection from Star Island against northeast and east storms, but is relatively unprotected to the south and southeast. White Island lies to the southeast, but it is too small to provide much protection.

Lunging Island was originally two separate islands. Longshore drift has transported material from both islands to form a bar which now connects the two islands to each other (Fowler-Billings, 1959).

Environmental Impact

Whereas there have been many large changes which have occurred over time, it is unclear what, if any, impact they have had on the area. This uncertainty is a result of the lack of published material about erosion of the Isles. It can be safely stated that due to the low population, the impact of erosion on the people and human-oriented resources has been minimal in recent times.

PISCATAQUA RIVER

Assessment of Changes

The Piscataqua River occupies a drowned river valley and extends from the confluence of the Salmon Falls and Cocheco Rivers in Dover to the sea in Portsmouth (See Map 13, page 90). The river is under tidal influence for its entire length, as are, for a limited distance, its two tributaries. The Piscataqua River is the means by which sea water enters the Great Bay estuary.



SOURCE : USGS Portsmouth, N.H. Quadrangle

The lower reaches of the Piscataqua River are bounded by steep bedrock cliffs on the New Hampshire shore. The river here follows its pre-glacial course which explains the incision into the bedrock (Goldthwait, 1951). The channel drops off very sharply near shore showing evidence that this cliff continues underwater. The cliff resists the erosive effect of the tidal currents relatively well and any erosion that occurs is the result of prolonged tidal scouring. This scouring has occurred over a very long period of time and the small, unnoticeable changes have accumulated and are now visible as the bedrock cliff on the west bank of the Piscataqua.

Little noticeable sedimentation takes place within the channel. Although there is sediment in suspension carried along by the tidal currents, there are few opportunities for deposition. Due to the depth of channel and the large volume of water which must flow in and out through it daily, the sediment in suspension remains in suspension until it arrives in a lower energy environment such as Great Bay or the Atlantic Ocean.

There are glacial deposits along the Piscataqua which are eroded by the current. One such area is the point located directly adjacent to the Dover Point Bridge on the eastern side. The bank has been cut back as evidenced by the scarp at the water edge and the tilting of adjacent trees toward the water.

The scarp is only five to ten feet high because the deposit is of relatively low relief. The material is highly erodable glacial outwash.

Dover Point is skirted by floodplains which appear to have been eroded. This material is unconsolidated, and the whole point is protected by rip rap. The current velocity of the river at this point is very high, indicating that the rip rap was necessary to prevent further erosion.

Along the east shore of Dover Point, the 40-foot contour lies quite near the shoreline. This steep shore is prone to removal of all unconsolidated material by undercutting and slumping. Once this material is stripped from the bedrock core, it will limit further erosion.

Noticeable erosion along the Piscataqua is limited to unconsolidated material within reach of the water level. Other than these areas, bedrock provides natural resistance to erosion and no noticeable changes occur for the short term.

Accretion, on the other hand, occurs regularly along the tidal flats which border the channel, predominantly north of Dover Point. These flats are exposed at low tide and in places extend several hundred yards from the shore. The flats are in constant change, as some material is removed regularly, and replaced by new material which is transported into the area.

The presence of these flats points out an interesting feature. Although the current velocities are extremely high, the fastest moving water stays in the deepest part of the channel. This phenomenon occurs because the drag over the flats is considerable, and the resistance in the deeper areas is far less. The mud flats act as a buffer between the actual high water shoreline and the maximum current velocities which occur in the channel. This is another reason that erosive changes are relatively small along most of the Piscataqua.

Environmental Impact

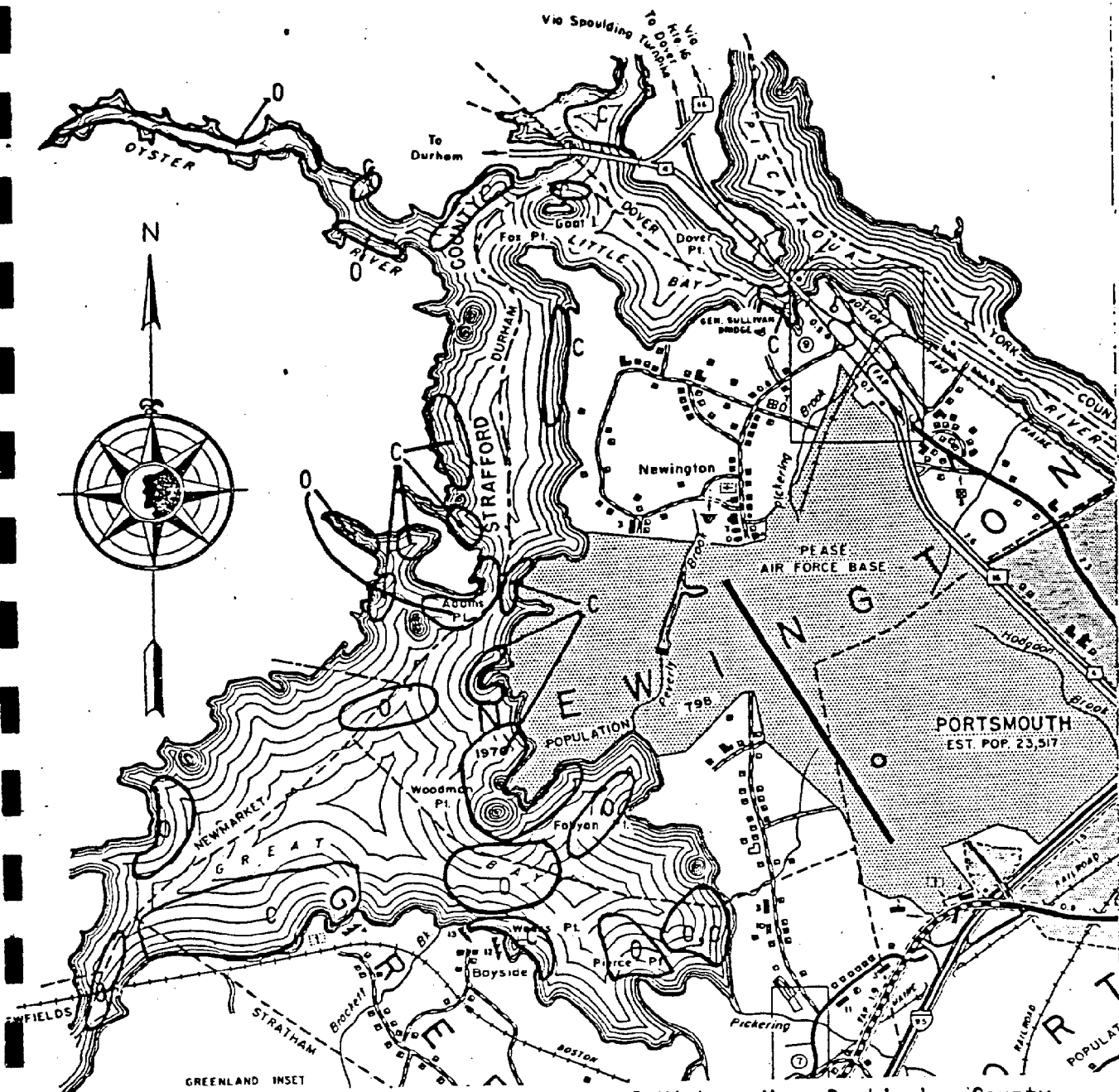
The large mud flats bordering the Piscataqua channel north of Dover Point are a haven for clams and the channel itself is dotted with large oyster beds (see Map 14, page 93). These shellfish beds represent a valuable recreational resource of the area. The clam beds are made possible by sedimentation along the banks while the oysters seem to prefer the currents in the channels. In both cases the shellfish depend on the environment for their existence. Therefore the changes, such as the sedimentation along the banks and the scouring of the channel, have had a marked beneficial impact on the existence of the shellfish beds.

OYSTER AND BELLAMY RIVERS

Assessment of Changes

As shown on Maps 14 and 15 (pages 93 and 94), the Oyster and Bellamy Rivers converge into the Little Bay access channel to the west and north of Fox Point and then out through the Dover Point strait to the Piscataqua River and to the sea. The flood currents are quite different. The incoming tide flows up both rivers, and also around Goat Island to Fox Point where the flow continues into Little Bay.

The flow between Goat Island and Cedar Point has caused some erosion of the mainland. Cedar Point has some large boulders scattered on the mud flats and in deeper water. These boulders give a rough estimate of the original extent

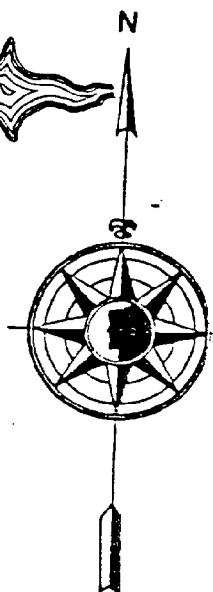
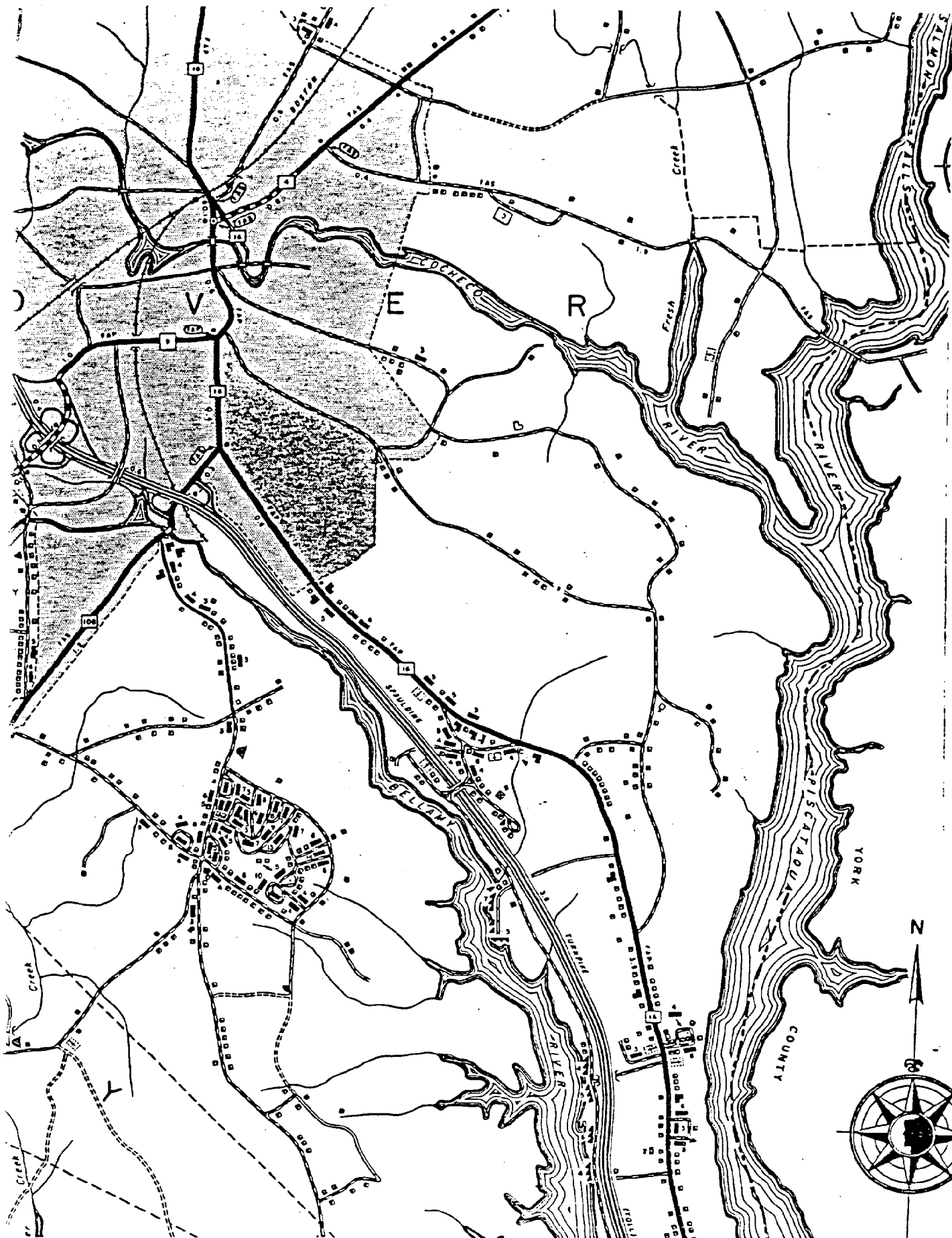


SOURCE: General Highway Map, Rockingham County

KEY

- O - Oyster Bed
- C - Clam Bed

MAP 14



SCALE 1/15,840

0 1/4 1/2 3/4 1 MILE

of the point. When the point is eroded, the boulders are dropped from their original position in the glacial deposit and are moved little from this position. The boulders indicate an extension of the headland out towards Goat Island and towards the Bellamy River. The erosion here is clearly the work of tidal currents.

Goat Island has also been reduced in size by the tidal currents, most evidently on the southern side, facing Fox Point. Between these two land bodies pass much of the tidal flow to and from Great Bay each day. The high velocity current removes material from the south side and deposits some of it in the form of mud flats which extend the full length of the island on the north side.

In addition, the northeast facing side of Durham Point has been cut back by tidal currents which flow nearby. Some of the eroded material is transported around the point to the west by the flood currents where it is deposited as a mud flat.

Environmental Impact

The only change with a noticeable impact has been the deposition of mud flats along the edges of these rivers. These mud flats provide a suitable habitat for shellfish, specifically oysters in the lower Oyster River and both clams and oysters in the lower Bellamy. This impact is beneficial as it allows the proliferation of these two species of shellfish.

LITTLE BAY

Assessment of Changes

Little Bay extends from Great Bay on the south to its convergence with Oyster and Bellamy Rivers on the north (See Map 14, page 93). This body of water is the channel by which Great Bay flows to the sea and hence there are high tidal velocities recorded here. All the water which flows into Great Bay during flood tides, in addition to the water added to this volume by the feeding rivers, must flow out during ebb tides. The convergence of this huge volume of water into the funnel of Little Bay causes extreme current velocities in the Furber Straits area near the mouth of the bay, and along the Little Bay channel.

The scouring effect of these currents is very effective in keeping the channel clear and free from sedimentation. As occurs in the Piscataqua, there are mud flats which line the channel area. These mud flats are subject to sedimentation and periodic erosion. These changes are so small and occur so frequently, that the overall effect is stability. In other words, what is eroded one day is filled in the next, so the overall change is negligible.

As shown on Map 14, the mud flats are extensive in Little Bay, with only Fox Point, Adam's Point and the unnamed point across the strait from Adam's Point projecting through the flats to the channel area. The mud flats provide protection from current erosion by buffering the shore from the most erosive currents which flow in the channel. These three headlands which receive no protection from the channeling of the flow bear the full brunt of the current of their shores.

On Fox Point, near the mouth of Oyster River, ebb tidal currents have caused erosion of the southwest facing shore. The currents have undercut the glacial material which composes the point and the material has slumped accordingly. Some of the slumped material is borne northwest with the current and deposited as a bar, growing from the point itself. This bar is very small, so it is more likely that most material carried in this direction is transported further around the point towards Broad Cove where a large mud flat is evidence of sedimentation.

A small bar extends southeast from Fox Point into the adjacent small cove. A series of Soil Conservation Service aerial photographs starting in 1940 indicate the continuing growth of this bar. The material most likely originates from the slumped material liberated at the eroded southwest side of Fox Point. Transportation results from both flood tidal currents which move in that direction, and from an eddy current which occurs during ebb tide.

This eddy tails off from the main ebb current and follows the shoreline southeast until circling back and rejoining the main current. This current can transport material from the eroding portion of the point towards the bar which is extending into the adjacent cove.

Adam's Point protrudes into the channel forming the western side of the Furber Strait. Despite the point's proximity to the high current velocity in the channel, erosion has been limited by the bedrock. The bedrock crops out all around

the point, with varying amounts of beach material and overlying soil. With the exception of the outer part of the point, there are mud flats extending both north and south.

The only erosion to note is occurring along the south and southeast facing shores. These shores face the largest fetch possible in the estuary, and hence bear the attack of the largest waves generated in the bay. These waves, in conjunction with ebb currents, have caused erosion of the toplayer of soil and glacial material which has partially been removed along this section of Adam's Point.

Along the point opposite Adam's Point, the erosion is caused by ebb and flood tidal currents. The point is characterized bedrock exposed at the shoreline. Erosion is most pronounced to the unconsolidated material covering the bedrock. This material is stripped with ease by the currents, when it is exposed. It is usually protected by the presence of the underlying bedrock which is more resistant to erosion. However, even the bedrock recedes, though at a slow enough rate that it is only noticeable over the long term.

An interesting feature of the shores bordering Little Bay is the different composition of east and west shores. The western shore, located in Durham, is composed almost entirely of bedrock. Where covered by glacial deposits, bedrock is not far below the surface. However, on the eastern, Newington side, there is very little bedrock in evidence along the shoreline. There is a large glacial outwash deposit here, with massive sand and gravel deposits mapped along the northern Newington shore. Along the southern expanse, from Furber Strait to Woodman Point, bedrock is closer to the surface, especially at the promontories which protrude into the channel.

Furber Strait itself is a deep, narrow channel which restricts the flow of water into Great Bay, limiting the intrusion of sea water and hence keeping the salinity slightly lower due to the two major fresh water rivers feeding it. The strait is one mile wide and 30 to 50 feet deep and is scoured clean by the high velocity tidal currents which flow through it four times a day.

To summarize, the changes which have taken place in Little Bay are by and large minor and measurable only over the long run. These changes have occurred where protruding headlands project into the channel.

Environmental Impact

The growth of the bar at Fox Point has had beneficial impact on the shellfish of the region. As the bar has extended to the southeast it has become a haven for clams. In addition to this minor bed there are other more extensive clam beds bordering the channel on the mud flats. There is a large oyster bed on the south and east of Adam's Point. All these shellfish beds owe their existence to the sand and silt substrate in the region. The substrate is a result of long-term sedimentation which has been occurring since the bay was flooded by rising sea level.

This area of the estuary still possesses a high level of aesthetic appeal. The scenic attributes of Little Bay have been little impaired by the changes in the shoreline.

GREAT BAY

Assessment of Changes

While the term Great Bay at most times connotes the entire estuary from the Piscataqua River to the feeding rivers, it refers here to the area inside of the Furber Strait (See Map 14, page 93). Great Bay is a large body of water which is fed both by the tides and by the fresh water from the Lamprey, Squamscot, and Winnicut Rivers. This mixing of fresh and salt water makes the bay a highly productive ecological region.

Great Bay is the innermost part of the estuary system and therefore is the least affected by salt water. The salinity here is slightly less than at other parts of the estuary. The bay also is one of the quieter environments within the system. For this reason, there has been very little erosion. However, sedimentation has been massive.

This sedimentation is one of the natural processes which occur in most estuaries. The feeding rivers carry a sediment load to the bay where the decrease in flow energy allows the load to settle out. Accordingly, the bay is ringed by massive mud flats with an outer ring of peat and marsh grass. These mud flats act as a buffer to the shoreline from any waves or currents which are capable of erosion.

One factor which affected the bay's sedimentation rate was the wasting of the eel grass in the early 1930's. A fungus, transported from Europe, destroyed the grass in a very short period of time. Prior to wasting, the root system of the eel grass helped stabilize the bottom sediments. The grass itself even acted as a trap to water borne material by removing it from transport and protecting it from the currents. The death of the eel grass in turn removed the stabilization which the root system rendered to the sediments.

The changes which resulted were major. There was large-scale slumping of steep channel banks. Much of this slumped material was then transported away by the currents. This had no significant impact on the major channels, because the tidal action kept the channels cleared. However, there was a substantial impact on the minor channels which had been stabilized by the eel grass during a previous flow pattern. When slumping occurred, there was not a high enough velocity current to carry the material away and maintain the pre-existing channel. Hence the slumped conditions prevailed and when stabilization re-occurred with the re-establishment of the eel grass in the 1950's, it occurred under slumped conditions.

In addition to changes in channel form and layout, shoals which had been stabilized by the eel grass also were affected. As the tides washed the liberated sand and silt to and fro over the shoals, often migration in one direction occurred.

An analysis of flow patterns within Great Bay can give light to which areas are more prone to erosion or sedimentation. As shown on Map 14, the major channel through the bay originates at the convergence of the Lamprey and Squamscott Rivers and trends northeast towards the middle of the bay, where it bears north and deepens into the Furber Strait.

The Winnicut River in Greenland contributes a limited flow to the bay. As a result, the eastern lobe of the bay experiences much less current action than the western lobe and therefore experiences a greater sedimentation rate. At low tide, the deepest section of the eastern lobe is just ten feet.

By and large, the currents which flow through these channels scour the bottom, but have little influence on the shoreline. One exception is Thomas Point at Pease Air Force Base, Newington. This point, has experienced erosion of its

west facing shore and has lost a large amount of material. It is susceptible to erosion because of its low-lying character and exposure to wave action.

Another form of erosion in the bay occurs only during the winter months when the bay freezes over. The ice often will freeze solidly to large chunks of peat at the periphery of the bay. As the tides rise and fall, the ice also rises, falls, buckles, and cracks. This buckling of the ice adjacent to the shore often loosens these blocks of peat which are attached to the ice. As the ice melts and breaks up in the spring, these blocks of peat are rafted away by the buoyant ice until, upon melting, the peat is dropped by the ice. Usually the rafting doesn't involve long transport. Isolated clumps of peat are often visible offshore from peat beds.

Ice blocks also affect the peat in another way. An ice block, as it rests against a shore of peat, will refract oncoming waves around it to concentrate on the peat behind and below it. The result is small isolated pockets of erosion along the salt marsh shoreline.

Environmental Impact

The major impact on Great Bay was the wasting of eel grass in the 1930's. The loss of stabilization and ensuing migration of sediments caused a large decrease in the shellfish population. Shifting shoals buried and killed large numbers of shellfish, both softshell clams and oysters. In addition, the shifting removed the protection from other shellfish beds leaving these organisms vulnerable, especially the very young shellfish.

Even in fringe areas, away from major currents, the impact of this change was felt. The fine particles which were held in suspension following erosion of shoals within a higher energy environment settled out when they approached a more protected area. Even a thin veneer of deposited silt can prevent oyster larvae from living in the area (Jackson, 1944).

The various organisms which used to live in and derive protection from the eel grass were also affected by its demise. Small fish, shrimp and creatures of this nature were displaced by the disappearance of their habitat, and their population declined accordingly. In addition, some species of fish laid their eggs in the eel grass and the lack of eel grass had a detrimental effect on their reproductive cycle (Jackson, 1944).

However, most of these impacts were reduced as the eel grass reasserted itself in the 1950's. Today it thrives throughout Great Bay and the whole estuary.

The sedimentation which occurs naturally in Great Bay has had a beneficial effect on the shellfish in the region. Shellfish, especially clams and oysters, require a sandy substrate to burrow in. This sedimentation, which has taken place over a very long term, has formed suitable growing conditions for the shellfish. Although periodic erosion may disrupt some of the shellfish beds in the region, most of the beds are in protected, low energy environments where erosion is usually not a concern (see Map 14, page 93).

ALTERNATIVE METHODS OF CONTROL IN AREAS EXPERIENCING SIGNIFICANT SHORELINE CHANGE

The 1978 report listed ten of the thirty sites described in the previous section, as problematic. As stated previously, two of those areas were deleted and three added. The eleven sites are showing signs of significant erosion or accretion which suggests that mitigation measures would be appropriate. The 11 locations, and associated mitigation measures (from the 1978 report), were reviewed by Kimball Chase Inc., consulting engineers in July, 1986. Each mitigation measure was amended by Kimball Chase, who is responsible for the following information entitled "Action Plans", "Project Breakdown", and "Alternative Methods of Control". It must be stressed that the accompanying construction cost estimates are in 1986 dollars and are to be considered "gross order of magnitude estimates". The gross order of magnitude estimates deal with rough quantities and very general assumptions only to the effect that they give a rough cost of the project for planning purposes. The estimates are based upon a visual interpretation of existing site conditions as they appeared at the time this report was prepared.

Specific reference to "Alternate Method of Control" refers to mitigation measures described in the 1978 report. Recommendations made in the current report are based upon visual inspection, past reports, and other available data. Recommendations and specific goals must be reevaluated at the completion of future feasibility studies. Individual Site Estimates utilized available USGS maps.

ACTION PLANS

The designated projects have been costed based upon the specific recommended mitigation plan. These cost estimates are to be used only for long range planning or prioritizing purposes. There is insufficient data available at this time to further define the projects cost.

Each project has been divided into two categories, Major and Minor Project. Major projects being greater than \$250,000 and minor projects \$250,000 and below. Each project has also been categorized by the areas of impact as presented in Table I, page 104.

Based on information presented and data reviewed in compiling this report, the following action plan is recommended.

1. Each project should be prioritized and incorporated into a multi-year coastal plan.
2. As individual projects are selected for action, the project's scope must be defined and engineering performed.
3. Funding for these projects should be broken into the 3 district phases listed below:
 - Feasibility Study through Preliminary Engineering
 - Final Engineering & Permitting
 - Construction/Implementation

Each phase will define the cost and magnitude of the succeeding phase including the phase's scope and funding requirements.

PROJECT BREAKDOWN

TABLE 1

Major Projects

<u>Location</u>	<u>Aesthetic</u>	<u>Economic</u>	<u>Environment</u>	<u>Recreation</u>	<u>Safety</u>
Hampton Beach (North End)	*	*	*	*	*
North Beach	*	*	*	*	*
Rye Harbor (North Shore)	*	*	*	*	*
Straw's Point	*	*	*	*	*
Foss Beach	*	*	*	*	*

Minor Projects

<u>Location</u>	<u>Aesthetic</u>	<u>Economic</u>	<u>Environment</u>	<u>Recreation</u>	<u>Safety</u>
Hampton Harbor Inlet		*		*	*
Seabrook Dunes	*	*	*	*	*
Little River Saltmarsh	*		*		
Bass Beach Saltmarsh	*		*		
Varrel's Point	*	*	*		*
Parson's Creek Saltmarsh	*		*		

Note: This Table is a compilation of concerns addressed in the following References:

- * Assessment, Impact and Control of Shoreline Change Along New Hampshire's Tidal Shoreline - Strafford Rockingham Regional Council, 1978.
- * New Hampshire Coastal Program Ocean and Harbor Segment and Final Environmental Statement - U.S. Department of Commerce, National Oceanographic and Aeronautic Administration Office of Coastal Zone Management, April 1982.
- * Shoreline Change in New Hampshire, Work Product #1 - Rockingham Planning Commission, May 21, 1986.

SEABROOK BEACH

(Map 5, page 39)- Continued human trampling and recreational vehicle traffic kills the beach grass which stabilizes the dunes along Seabrook Beach. Sand, once anchored by the root system, is liberated and subject to wind transport. This debilitation of the dunes at Seabrook Beach has reduced protection from storms for structures behind the dunes. Because development has taken place on the dunes, the dunes need to be stabilized. It is these stabilizing structures (e.g. seawalls and riprap) that interrupt the natural recession of the bar system, by eliminating the overwashing and breaching caused by storm waves.

Mitigation Measures Since 1978 - Cottage owners along the north end of the beach have placed riprap along the base of the dunes in an attempt to slow the erosion process. The Corps of Engineers reports that these piecemeal protection structures are only about 80 feet from the high tide line and within easy reach of storm waves (Corps of Engineers, 1962).

Another area that needs attention is 53 acres in the southeast corner of the town -- the only remnant of a natural and complete back dune system in New Hampshire. It is bordered on the south by a small portion of salt marsh which separates it from adjacent commercial properties. The northern boundary is formed by the salt marsh and Cross Beach Road (unimproved). On the east, the dunes abut Route 1A for approximately one mile.

Much concern has arisen over this precious area which is deteriorating. As a result, the Town has appropriated \$250,000 and is expecting \$100,000 in Coastal Zone Management funds for the purchase and preservation of the area. The final appraisal is expected by June 11, 1986 with purchase to follow as soon as possible.

Alternate Methods of Control (Kimball Chase):

A. Goal - Limit number of foot paths through dunes

This method of control is recommended for the Seabrook Beach area, however, there is a concern with the cost effectiveness of parallel foot paths behind the dunes. This would be an item that would be addressed in the feasibility study and preliminary engineering phase.

The probable results of successful regeneration of the dune system seem accurate. The economic and environmental justification appears to be well founded.

Action:

	<u>Estimated Cost</u>
- Construct 600 lineal feet (lf) of 6' wide boardwalk foot paths over dunes	\$ 25,000
- Construct 8000 lf of 6' wide boardwalk, parallel and behind dunes to provide access to boardwalk paths over dunes.	200,000
- Construct 4000 lf of snow fencing across closed paths of block access and trap blown sand.	15,000
- Nourish closed paths with approximately 10,000 cy of sand and plant beach grass to stabilize the loose sand.	45,000
- Feasibility Study and Preliminary Engineering	32,000
	=====
Total	\$ 332,000

Note:

1. Estimates do not include R.O.W. easements or land purchases.
2. Estimated design life of timber boardwalks is 7 - 10 years with normal regular maintenance.
3. Feasibility Study and Preliminary Engineering includes survey and extensive assessment of entire dune system.

B. Goal - No expenditure; no action

This is not a viable nor prudent alternate method of control. The probable results of increase erosion and risk of breaching are accurate. There is no justification for this alternate method, economically or environmentally.

HAMPTON HARBOR INLET

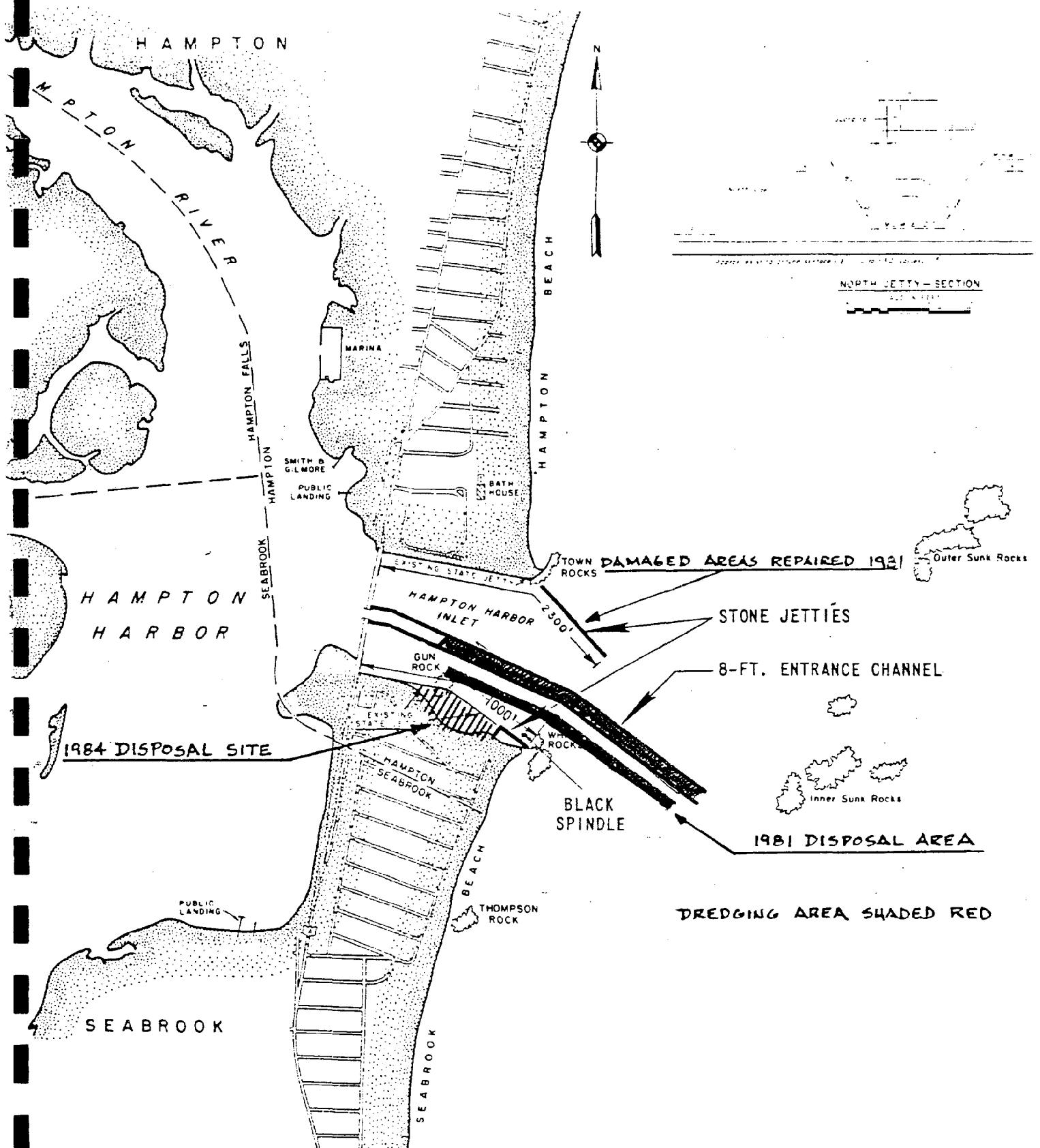
(Map 5, page 39) -Stabilization of the inlet by the construction of jetties (1934-35) has interrupted the longshore transport of sand by trapping it behind the jetties. Accretion has occurred on the north side of the Hampton jetty, on the south side of the Seabrook jetty, and on a bar offshore. Tidal scouring of the Hampton - Seabrook bridge pilings has weakened the pilings and necessitated the placement of large boulder riprap at their bases.

Accretion within the inlet necessitates periodic dredging which does great damage to vegetation and shellfish. The shellfish industry and the ecology of the estuary are negatively impacted by the dredging process, during which vegetation is uprooted and displaced. Seed, as well as adult clams, are destroyed at the dredge site so that the impact is felt not only immediately, but also over the long run. The increased turbidity and suspended solids can smother other shellfish many miles from the dredging site when the particles settle out of suspension. Even a thin layer of sedimentation can kill seed clams and render the area unsuitable for future use as a clam nursery (Clark, 1974).

Mitigation Measure Since 1978

- 1980 -- 76,310 c.y. dredged from the Hampton & Seabrook Public Marina Areas (22 acres total). The majority of the spoils were placed inside the south jetty. The remainder was placed in the Hampton State Park to dry out and then carried north and dumped on Hampton Beach near the Church Street groin.
- 1981 -- North jetty in Hampton Harbor Inlet repaired.
- 1981 -- Maintenance dredging in Hampton Harbor Inlet: 50,000 c.y. (See Fig.10, page 108)
- 1984 -- Maintenance dredging in Hampton Harbor Inlet: 27,900 c.y. (See Fig.10, page 108)

FIGURE 10



Alternate Methods of Control (Kimball Chase):

A. Goal - Keep channel safe and clear for navigation.

This is clearly the preferred and proven method of control for the Hampton Harbor Inlet area. A side-caster dredge will hydraulically pump material from the center of the channel and deposit it on the edges of the channel. Every two years, this material which is predominately sand can be pumped or trucked to the north end of Hampton Beach adjacent to Great Boars Head. The probable results are a predictable level of accretion. Detrimental effects on shellfish may be valid, but will be dependent and the sophistication of the side-caster system used as well as the season during which the operation would be carried out.

Action:

	<u>Estimated Cost</u>
- Yearly use a side-caster dredge to remove approximately 10,000 cy of material in main channel and harbor.	\$ 20,000 per year
- Every two years hydraulically dredge approximately 40,000 cy of material from harbor and inlet and transport it to north end of Hampton Beach adjacent to Great Boars Head and/or Wallis Sands Beach as beach nourishment.	\$250,000 every 2 years
- Feasibility Study & Preliminary Engineering	\$ 15,000 =====
Total Costs	\$160,000 first year 145,000 following year

Note:

1. No inflation factor has been applied for future years.
2. Feasibility study and Preliminary engineering would study options to yearly maintenance dredging such as adjusting and/or extending jetties to minimize accretion.

- B. Goal - Protect Route 1A bridge pilings from pilings from subsidence due to under cutting.

The present action that the DPW&H has done and is continuing to do is the best solution to this problem. The past history supports the probable results and economic justification.

- C. Goal - Laissez-faire maintenance

This is not a viable nor prudent alternate method of control. In addition to the probable results of unabated sedimentation in harbor, narrowing and shoaling of channel and growth of offshore sand bar, would be the compromising of the structural stability of the Route 1A bridge pilings. There is no economical nor servability justification for this alternate.

HAMPTON BEACH, NORTH END

(Map 7, page 52)-Development adjacent to Hampton Beach consists largely of motels, hotels, and other tourist-based establishments. In order to protect this large investment from the onslaught of the sea, the State of New Hampshire constructed a seawall in front of the business center in 1946-1947 with a riprap revetment at its base along the southern sector. Rather than retarding it, this seawall structure has hastened erosion. During storm activity, waves' break directly on and over the seawall which also concentrates the breaking waves energy at its base and promotes scouring of the beach face. In fact, at the northern end of Hampton Beach, northeast swells are reflected by the concave seawall in a southerly direction, toward the beach, adding to the erosive force of the longshore current.

Due to the orientation of the beach and to the refraction of waves around Great Boar's Head, the longshore current at Hampton Beach is southerly from Great Boar's Head. As mentioned previously, wave energy is concentrated around headlands, such as Great Boar's Head, because wave refraction effectively bends the waves in toward the headland from all sides. Originally, the result was rapid erosion: waves breaking on Great Boar's Head carried the smaller, lighter sediments in a southerly direction along Hampton Beach (and, in a northerly direction along North Beach). The larger sediments were dropped in place and transported only by waves large enough to move them. The result was a higher percentage of cobbles and shingles at the northern end of Hampton Beach and around Great Boar's Head than farther south along the beach.

With the development of Great Boar's Head, came the need to limit erosion of the headland. Erosion had been controlled naturally to some degree, by the larger boulders which had been eroded and dropped in place, but it has been further reduced by the construction of riprap revetment around the entire point.

This work has effectively halted the supply of material from Great Boar's Head to Hampton Beach. The longshore current, however, still continues to flow south and accordingly transports material from the north to the south. The result is erosion at the north part of the beach, because material is removed but not replaced.

Mitigation Measures Since 1978 - None

Alternate Methods of Control (Kimball Chase):

A. Goal - Natural replenishment of beach sand.

This alternate method of control, the removal of stabilization devices from Great Boars Head, is a viable method though not recommended. In addition to the probable result of increased incoming sediment to Hampton Beach, would be the significant loss of land at Great Boars Head. (The replenishment of sand on the beach must be significant enough to justify the substantial loss of land from Great Boar's Head.)

B. Goal - Maintain wide beach by means of beach nourishment.

This method of control is an acceptable one that has worked in the past. The probable results of a wide sand beach, low erosion rate at Great Boars Head, and constant replenishment maintenance are reasonable probable results. Further studies and bio-assays would be required to determine the extent of marine organism degradation in the deposition areas. The economic and recreational justification seem reasonable but would require further economic analysis and study.

Action:

	<u>Estimated Cost</u>
- Place 250,000 cy of sand over beach as initial nourishment to return it to its 1973 profile.	\$1,000,000
- Every two years hydraulically dredge approximately 40,000 cy of material from Hampton Harbor and the inlet, and transport it to Hampton Beach adjacent to Great Boars Head.	250,000 every 2 years
- Feasibility study and Preliminary Engineering	15,000 =====
Total Costs	\$1,265,000 first year \$ 250,000 every following 2 years

C. Goal - Maintain wide beach by means of beach nourishment and groin field.

This is the preferred method of control for Hampton Beach (north end). This method combines the action items from Plan B. with a groin field. The probable results are the same as with Plan B. with the addition of slower sand migration and the reduction in marine organism degradation due to decreased beach nourishment requirements. In addition to the justifications listed in Plan B. would be the additional economic justification of the groin fields which would require detailed technical and economic study.

Action:

	<u>Estimated Cost</u>
- Place 250,000 cy of sand over beach as initial nourishment to return it to its 1973 profile.	\$1,000,000
- Every two years hydraulically dredge approximately 20,000 cy of material from Hampton Harbor and the inlet, and transport it to Hampton Beach adjacent to Great Boars Head.	125,000 every 2 years
- Construct seven, 300' long groins along Hampton Beach.	
a. Quarry Stone Groins	1,300,000
b. Timber Sheet Pile Groins	250,000
- Feasibility Study and Preliminary Engineering	50,000
	=====
Total Costs a.	\$2,475,000 first year 125,000 every following 2 years
Total Costs b.	\$1,425,000 first year 125,000 every following 2 years

Notes:

1. Feasibility study and Preliminary Engineering for B. includes soundings, bulk sediment analysis, survey and other engineering data required.
2. Feasibility study and preliminary Engineering for C. includes all items in B, plus extensive studies into impeding sand migration and preliminary design of recommended structures (i.e. groins or breakwaters).
3. Estimated design life of timber sheet pile groins is 7 - 10 year with normal regular maintenance.
4. Estimated design life of Quarry stone groins is 20 + years with normal regular maintenance.

NORTH BEACH

(Map 7, page 52)-Development along North Beach is similar to that at Hampton Beach, with the exception of depth. Development at North Beach does not encroach back upon the marsh as much as at Hampton Beach, though both occupy the site of previous dunes. As at Hampton Beach, the development required protection which was subsequently provided by the construction of a concrete seawall (1935-1937) along the north section of the beach. Later (during 1955-1956), a sheet pile bulk head was built from the south end of the concrete seawall, south to Great Boar's Head.

As the natural recession of the shore-line proceeds, the shoreline has moved toward the seawall, but the seawall cannot move landward as a dune system would. Hence, the beach becomes narrower due to the seawall's immobility and its inability to supply sand to the beach as a dune would. As with the Hampton Seawall, waves break on the North Beach seawall, their energy is concentrated and reflected down toward the beach and back toward the ocean, carrying away large quantities of beach material.

In addition, stabilization of Great Boar's Head has cut off the supply of beach material to North Beach.

The result of these various factors is extensive erosion which has left North Beach so narrow that it serves none of the natural protective functions of a beach. High tide storm waves send water crashing over the seawall, carrying with them kelp, cobbles, and sand. The seawall and road have been subjected to serious wave action and damage to both has occurred.

Mitigation Measures since 1978 - After the coastal storm of 1978, the Hampton Seawall (on North Beach between Great Boar's Head and Plaice Cove) was capped. The seawall is now in poor condition. It is anticipated that the matter of funding the seawall will be acted upon during the 1987 session of the General Court.

Alternate Methods of Control (Kimball Chase):

A. Goal - Natural Replenishment of Beach Sand.

This alternate method of control, though not recommended, removing of stabilization from Great Boars Head, is a viable method. In addition to the probable result of increased incoming sediment to North Hampton Beach, would be the significant loss of land at Great Boars Head. (As is the case at Hampton Beach, the replenishment of sand on the beach must be significant enough to justify the substantial loss of land from Great Boar's Head.)

B. Goal - Leave beach as is; protect seawall and Route 1A.

This alternate method of control is technically acceptable to maintain the existing system of shore protection. The probable results of continued loss of beach area and eventual seawall deterioration are reasonable results for this particular area. The justification of less expense than Plan A is only correct if the existing steel seawall is not replaced. If the steel seawall is replaced then there is a financially substantial action item.

Action:

	<u>Estimated Cost</u>
- Replace 3900 lf of steel seawall and bulkhead.	\$7,200,000
- Place 4000 lf of random and irregular armor stone riprap at base of seawall and bulkhead.	1,200,000
- Feasibility Study and Preliminary Design	50,000
	=====
Total	\$8,450,000

C. Goal - Maintain Seawall and bulkhead as at present.

The addition of shingles is not necessary and may actually worsen the situation. If the stone riprap armor suggested in Plan B is placed in a random and irregular manner it will provide sufficient wave energy dissipation.

D. Goal - Maintain seawall and construct a wide sand nourished beach.

This alternate method of control is recommended with some modifications. The action items should include all items in Plan B. plus a groin field and beach nourishment. The probable results would be a wide sand beach with minimum nourishment requirements. The justification for this plan are economic and recreational, and would require further study.

Action:		<u>Estimated Cost</u>
-	Replace 3900 lf of steel seawall and bulkhead	\$7,200,000
-	Place 4000 lf of random and irregular armor stone riprap at base of seawall and bulkhead.	1,200,000
-	Place approximately 190,000 cy of sand over 7900 lf of beach in major nourishment program.	750,000
-	Replace approximately 20,000 cy of sand over 7900 lf of beach in nourishment program every two years.	80,000 every following 2 years
-	Construct seven, 300' long groins along beach	
	a. Quarry stone groins	1,300,000
	b. Timber Sheet Pile groins	250,000
		=====
-	Feasibility study and preliminary design	50,000
	Total Costs a.	10,580,000 first year 80,000 every following 2 years
	b.	9,530,000 first year 80,000 every following 2 years

Note:

1. The estimated cost for the replacement of 3900 lf of steel seawall and bulkhead is from C.E. Maquires Engineering study done in the Winter of 1986.

NORTH HAMPTON BEACH - LITTLE RIVER SALTMARSH

(Map 8, page 59)-The growth of a barrier bar across the entrance to the Little River Saltmarsh has made some radical changes in the marsh's drainage pattern. The marsh used to undergo tidal flushing action through an inlet at the middle of the beach. This inlet has migrated 300 feet north as a result of the northerly longshore current. Subsequently this longshore transport has moved enough sand into the inlet to close it off. In an effort to reopen the marsh the state constructed a 4 foot culvert at the north end of the marsh to allow drainage (Corps of Engineers, 1962). Both the flood of tidal water into the marsh and the flow out of the marsh from the Little River are restricted to this 4 foot opening, the only open connection between the marsh and the ocean. As a result, not enough saline tidal ocean water flushes up into and then back out of the marsh, resulting in the marsh's deterioration.

The decrease in salinity in the marsh has caused the invasion of terrestrial and freshwater marsh plants. The most obvious and aggressive of these is purple loosestrife which now covers approximately 60% of former marsh area. The invasion of purple loosestrife is a sure indicator of degradation and loss of salt marsh area.

The ecology of the marsh is suffering and the potential exists for greater damage to occur and for total eradication of shellfish and scattered vegetative life, and ultimately the total breakdown of the saltmarsh community.

Mitigation Measures Since 1978 - Frederick T. Short, Ph.D., in his report entitled "North Hampton Salt Marsh Study", recommends two mitigation measures. Normandeau Associates, Inc. of Bedford has drawn up preliminary engineering plans for this area based on Short's recommendations.

1. Install a 48' diameter culvert under Route 1A. This culvert would extend from the Little River as it passes the north side of Fifield Island to Godfrey's Ledge, offshore. The recommendation to extend the pipe out into the ocean was made in an effort to circumvent the potential problem of the seaward end of the culvert filling with sand. Approximate cost \$1,500,000.00.
2. Construct a drainage swale starting near the fish house culvert and running parallel to the shore over to Little River at the North Side of Fifield Island. To ensure that there would be adequate flow of salt water to the far reaches of the marsh, a 48-inch pipe must be constructed parallel to

the existing 48-inch pipe running under Route 1A, by the fish houses, to the ocean. Approximate cost \$200,000.

Alternative Method of Control (Kimball Chase):

Goal - Regeneration of degraded salt marsh by opening original inlet.

The installation of 72" pipe where a natural inlet was once located will improve flushing action of this salt water marsh. A detailed feasibility study and preliminary engineering may generate additional alternate methods of control. The justification is clearly environmental.

Action:

	<u>Estimated Costs</u>
- Install 700 lf of 72" R.C. pipe including excavation.	\$ 85,000
- Feasibility study and preliminary engineering	25,000
	=====
Total	\$ 110,000

Note:

1. Feasibility study and preliminary engineering would include study of reestablishing open channel with stabilizing jetties and review and possible interaction of materials developed by Normandeau Associates, based upon work prepared by Frederick T. Short in his report titled "North Hampton Salt Marsh Study".

BASS BEACH - BASS BEACH SALT MARSH

(Map 8, page 59)-The problem here is inadequate marsh drainage. Because large areas of the marsh are permanently covered with saline water, typical marsh plants have died out and pannes have formed. (A panne is an area where saltmarsh vegetation has died and the surface of the marsh has subsided, leaving standing water on the surface.)

It is difficult to say exactly what the cause of these pannes might have been. However, it seems certain that it is related to the mosquito ditches which were dug in the marsh surface in the 1940's creating high margins along the ditches where the earth was thrown. These ditches were unsuccessful and only served to promote degradation of the marsh. In addition, the water which floods the ditches is usually turbid -- carrying suspended sediments -- and deposits its sediments before receding, further exacerbating the drainage problem. Another contributing factor is the culvert under the old electric railway bed which further restricts the flow of water.

The panne areas support thriving colonies of blue/green algae and also many insects and, at least in the deeper channels, crustaceans and small fish. The fish and insects attract many shore birds, making Bass Beach one of the best birding marshes along the New Hampshire coast.

Although Bass Beach Marsh harbors many birds and is free of purple loosestrife, it is not a stable ecosystem. The size and extent of the pannes have increased rapidly in the past ten years, and, without intervention, can be expected to expand. If the process of panne formation goes unchecked, the marsh will eventually degrade and become inhospitable to birds and animals.

Mitigation Measures Since 1978 - Dr. Frederick Short's study, financed last year by the town of North Hampton and the State, suggested that the impediment to proper flow of salt water to and from the marsh is an old trolley trestle built in 1900. In March, 1986, Normandeau Associates, Inc. drafted preliminary engineering plans showing the removal of the railway trestle as recommended by the Governor's Coastal Advisory Committee. The plans show the replacement of the present culvert under the railway bed with an open channel to improve flushing of the marsh. There is some concern, however, that removal of the trestle may cause flooding on abutting properties. These designs are structural

and, to date, no comprehensive hydraulic studies or mapping associated with marsh regeneration have been undertaken.

Alternate Method of Control (Kimball Chase):

Goal - Regeneration of degraded salt marsh.

There is insufficient data to reasonably make an estimate of action items for this area of concern. Therefore, a feasibility study and preliminary engineering incorporating work recently completed by Normandeau Associates are recommended to assess the condition of Bass Beach salt marsh.

Action:

	<u>Estimated Cost</u>
- Feasibility study and preliminary Engineering	\$ 30,000

Note:

1. Feasibility study and preliminary engineering would include mapping and hydraulic modeling of salt marsh, and the generation of suggested solutions.

STRAW'S POINT

(Map 9, page 67)-The extensive erosion at Straw's Point has greatly affected the recreational and aesthetic resources of the point. The erosion has limited the use of the shore for bathing, and undermined the outer loop road, making it unusable. In addition, riprap placed along the outer periphery of the point to control erosion has decreased the aesthetic value of the point. The riprap limits the view and is itself unsightly.

Mitigation Measures Since 1978 - None

Alternate Methods of Control (Kimball Chase):

A. Goal - Private maintenance, as needed.

This alternate method of control includes the placement of riprap along the shore as necessary. Without detailed studies and engineering plans these minimal action items will not prevent significant erosion.

B. Goal - Complete stabilization.

This alternate method of control, the placement of riprap revetment along the entire shore, will significantly reduce the erosion but also cut off a supply of sand to Jenness Beach.

Action:

	<u>Estimated Cost</u>
- Placement of 2500 lf of 50' wide by 3' deep quarry stone riprap revetment.	\$1,200,000
- Feasibility study and preliminary engineering	10,000
	=====
Total	\$1,210,000

VARREL'S POINT

(Map 9, page 67)-Major erosion has had an adverse impact on the recreational, aesthetic, and economic resources of the area. As a barrier bar, the point once had a sand beach suitable for swimming and sunbathing. However, when the houses were constructed on the dunes, protective stone was placed where the beach had been. This riprap was placed at great expense in both money and loss of beach area. In addition, the riprap blocks the view from most of the houses on the point. While serving a necessary protective role, the riprap has reduced the scenic nature of the point.

Mitigation Measures Since 1978 - None

Alternate Method of Control:

- A. Goal - Continued protection by means of maintaining current armor stone revetment and jetty.

The continuation of this alternate method of control, which has proven itself to be an acceptable system of shore protection at this site is recommended. The probable results will be periodic maintenance after large winter storms, which is not unusual for any shore protection system. The economic and protection justification based on the existing investment is well founded.

Action:

	<u>Estimated Cost</u>
- Repair damage to revetment and jetty as needed.	\$ 20,000
- Feasibility study and preliminary design.	5,000
	=====
Total	\$ 25,000

RYE HARBOR, NORTH SHORE

(Map 9, page 67)-Between 1939-1941, two jetties were constructed to protect the harbor, which was previously open to the sea. The configuration of the jetties has exposed the north shore of the harbor to southeast swells. Not only are the jetties open to the southeast, but their layout actually channels these swells into the harbor. Riprap placed along the critical erosion area has slowed the erosion at that point, but storm waves still overtop the bank. The erosion has resulted in extensive loss of land and required considerable expenditures for protective riprap. In addition, the erosion has detracted from the natural beauty of the area, both through the loss of land and the unsightliness of the riprap.

An inner jetty was constructed to protect the channel draining Awcomin Marsh. This jetty acts as a trap for the outgoing sediment-laden water from Awcomin Marsh and therefore, promotes accretion. The sand builds up in the harbor, interfering with boating use and limiting the mooring capacity of the harbor. Dredging becomes necessary due to accretion within the harbor, and as is the case at the Hampton Harbor inlet, dredging is expensive and causes damage to clam and oyster beds.

Mitigation Measures Since 1978 - None

Alternative Methods of Control (Kimball Chase):

A. Goal - Stabilization of bank and Ragged Neck.

This alternate method of control is an acceptable solution to the problem at this area. Reduced erosion would be the probable result if the action items were completed.

Action:

	<u>Estimated Cost</u>
- Construction of riprap revetment continuous with the riprap which protects the state-owned property on Ragged Neck. This riprap should continue west to inner breakwater.	\$ 500,000
- Feasibility study and preliminary engineering	20,000 =====
Total	\$ 520,000

B. Goal - Reduce Erosion by limiting oncoming waves.

This alternate method of control would effectively block southeast swells thereby reducing shoreline erosion. The probable result of navigational risk is an item which would be dependent on location and orientation of a offshore breakwater. We feel this alternate method of control may have significant justifications which would be studied in a feasibility study and preliminary engineering.

Action:

	<u>Estimated Cost</u>
- Construct 600' offshore breakwater to block southeast swells.	\$ 600,000
- Feasibility study and preliminary engineering	50,000
	=====
Total	\$ 650,000

C. Goal - No expenditure; no action.

This alternate method of control is not the preferred method. The probable results of increased erosion seems accurate. There does not seem to be any clear long term justification for this alternate -- economically or environmentally.

FOSS BEACH

(Map 10, page 72)-The erosion of Foss Beach has had a negative effect on the recreational use of the beach and has imperiled the state highway located behind the shingle ridge. As at North Beach in Hampton, Foss Beach has suffered extreme erosion in the form of retreat of the shoreline, steepening of the beach face, and a change in beach material to much coarser shingles. The end result, as at North Beach, is an unusable beach, which is compounded by the presence of a protective steep shingle ridge. The steep ridge must be scaled in order to gain access to the beach.

This ridge, while performing an important protective function, also has an adverse aesthetic impact. It effectively blocks the view of the ocean not only from the road, but from the first floor of houses bordering Route 1A on the west. The erosive effect of the storm waves is to topple the ridge onto the road. Following the 1978 blizzard, considerable resources were required to clean up the road and reconstruct the ridge.

Mitigation Measures Since 1978 - None

Alternative Methods of Control (Kimball Chase):

A. Goal - Reconstruction of natural system.

This alternate method of control is the optimum and preferred method. The action items have been modified somewhat to provide a complete system of shore protection. Further study is required on this complex system. Justification will be based on recreational, economical, and environmental criteria.

Action:	<u>Estimated Cost</u>
- Level 60,000 cy of existing shingle ridge seaward to create parking and base for dune.	\$ 60,000
- Place 150,000 cy sand dune on leveled shingled.	600,000
- Place 100,000 cy of sand over 400 lf of beach as nourishment.	400,000
- Construct five, 300' long groins along beach.	

a.	Quarry Stone Groins	\$ 900,000
b.	Timber Sheet Pile Groins	150,000
		=====
-	Feasibility study and preliminary engineering	100,000
Totals	a.	\$2,060,000
	b.	\$1,310,000

B. Goal - Protection of Route 1A and development on western side of road at lowest possible cost.

This alternate method is a viable method of control for low budget requirements. The post storm clean-up and shingle nourishment action items are effective, short term low cost measures. The construction of an immobile core for the shingle ridge could be a significantly expensive action item depending on its configuration. The probable results of the destruction of road and buildings is possible if the immobile core is not completed. The short term economic justification seems reasonable based on limited development in the abutting lands.

Action:		<u>Estimated Cost</u>
-	Drive 20' timber piles at 10' o.c.	\$ 100,000
-	Pressure inject 12 cubic foot/l.f. of grout in core of shingle ridge.	95,000
-	Feasibility study and preliminary engineering	25,000
		=====
	Total	\$ 200,000

C. Goal - Continued Present Maintenance.

This method of control is not a preferred one. The probable results of destruction of the road and buildings are significant if yearly preventative maintenance is not performed as outlined in Plan B. There does not appear to be any viable justification to continue with this method of control.

D. Goal - Greater stabilization of shingle ridge.

Covering the shingle ridge with riprap is not an optimum alternate method of control. The probable results of a strengthened shingle ridge and reduced highway maintenance will be overcome by the reduced wave energy absorption of a riprap surface and lead to weakening of the toe of the shingle ridge. This seems to be a large expenditure for a short-term and a technically uncertain solution.

WALLIS SANDS BEACH - PARSON'S CREEK SALTMARSH

(Map 10, page 72)-"A combination of manmade and natural events over an extended period of time have contributed to the marsh's present condition . . . Degradation has resulted from an insidious process of small impacts over long periods of time." (Simpson, 1986)

Several factors have combined to reduce the frequency and distance of tidal inundation into the marsh and hence to promote degradation:

- Remains of a barge which came ashore in the late 1940's have caused the formation of a sandbar at the mouth of the creek. Seaweed and other debris, had, in the past been trapped here; their anaerobic decomposition has caused noxious odors and even damage to house paint.
- The bridge on Old Wallis Road has decayed and the stone abutments have fallen into the channel, damming the creek.
- Under New Wallis Road, debris, cement blocks, rocks, etc. were seen in the very shallow water 15 to 20 feet on either side of the bridge and under it (Simpson, 1986).
- On the property on the creek between the Red Roof Market and the horse paddock, the creek has been stabilized with an assortment of metal, wood, discarded household items -- all tied together with rope and cable. Periodically, debris falls into the creek, reducing the tidal flushing.
- Since 1970, progressive amounts of fill have been dumped on the marsh at the horse paddock. In 1971, a fence and small barn were erected on this filled area (Simpson, 1986).
- In 1963, Route 1A (Ocean Boulevard) was rerouted to improve the State Facility at Wallis Sands State Beach. This new section of road was built over salt marsh, separating a section of marsh from the main drainage system. Although culverts were placed under Route 1A, they became blocked over time.

Flushing of sediment and organic debris from the upper reaches of the marsh has been inhibited and the migration of ocean species in and out of the marsh is restricted and surface turf has decayed because of poor drainage.

Mitigation Since 1978 - Several points in the channels which were blocked by rocks and other debris have been cleared and a channel was dredged at Concord

Point. The tidal flow to the upper reaches of the marsh has been improved and the sedimentation problems at the mouth of the creek have been ameliorated temporarily. The enhanced flushing has helped to bring oxygen and saltwater to the far reaches of the marsh, to rid the marsh channels of sediments, and to promote revegetation by peat producing plants, reducing mosquito populations. However, further efforts are needed in order to restore the area.

- Dredging at Wallis Road should be expanded. The adjacent landowner has indicated a willingness to let machinery work from his land.
- The remainder of the rocks at Old Wallis Road should be removed with a backhoe.
- "Trash Corner" should be graded and rip rap placed to stabilize the bank and keep debris from falling into the channel.
- The horse paddock is stable, but organics, nitrogen, etc. are finding their way into creek waters.
- The "shallows", north of the horse paddock should be removed with a backhoe.
- The remains of the barge should be removed.

Alternate Method of Control (Kimball Chase):

A. Goal - Regeneration of degraded saltmarsh.

Previous mitigation measures have worked to the extent that they were incorporated. Additional action items would be to remove obstructions in the channel and install the previously proposed jetty. Probable results would be the continued flushing of the salt marsh as well as the stabilization of the channel in the tidal beach area.

Action:	<u>Estimated Cost</u>
- Remove obstructions in channel, from 200' north of Route 1-A to MLW.	\$ 5,000
- Install previously proposed 150' jetty to stabilize channel.	30,000
- Feasibility study and preliminary engineering	5,000
	=====
Total	\$ 40,000

GENERAL TYPES OF CONTROL DEVICES

- A. Bulkheads Metal sheeting or timber driven vertically into the ground and anchored by various means.
- Aim -To stabilize shoreline by providing an impermeable barrier.
- Applications -Along unconsolidated shores where structures (such as roads or buildings) need immediate protection from undermining and wave attack. For example, bulkheads exist at North Beach, Hampton (southern section), and part of Wallis Sands Beach, Rye.
- Disadvantages -Corrosion of steel by salt water.
- Drainage problems related to water from overtopping.
- Concentration of energy from breaking waves on bulkhead causes increased erosion of material in front of the structure.
- B. Seawalls Vertical, curved or stepped concrete wall.
- Aim -To stabilize shoreline by providing an impermeable barrier.
- Application -Along unconsolidated shores where structures (such as roads or buildings) need immediate protection from undermining and wave attack. For example, seawalls exist at Hampton Beach, North Beach, Hampton (northern section), Jenness Beach, Rye, and parts of Wallis Sands Beach, Rye.
- Disadvantage -Scouring at toe.
- Drainage problems behind structure related to water from overtopping.
- Concentration of energy from breaking waves on seawall causes increased erosion of material in front of structure.

C. Concrete
Revetments

Interlocking concrete blocks constructed on a bed of permeable crushed stone on a stable grade.

Aim -To stabilize eroding banks in a non-vertical position providing permeable protection from wave attack.

Application -Interlocking concrete revetments are best suited for areas where wave energy is slightly lower than the open sea where higher wave energy would merit a seawall or bulkhead. These revetments are useful in preventing undercutting of banks, where slumping is probable result.

Disadvantages -Difficult, costly to construct and maintain.
-Smooth surface makes poor substrate for most marine organisms.

D. Stone
Revetments

Also called riprap. As with the interlocking concrete type, riprap revetments are constructed on a bed of permeable crushed stone. By virtue of the loose fit of the stone blocks, riprap is easier to construct and thus, does not provide as much protection as the concrete type.

Aim -To stabilize eroding or unstable banks in a non-vertical position. Slope must be graded to a stable slope before device can be constructed.

Application -Riprap revetments can be used in most cases in place of interlocking concrete revetments, at much lower costs. In New Hampshire, most headlands are protected by riprap (for example, Great Boars Head, Little Boars Head, Varrel's Point, Ragged Neck, part of Odiorne's Point, Dover Point, and various other places in Great Bay).

-Riprap is also used to supplement seawalls and bulkheads by preventing scouring and undercutting.

-Riprap is very adaptable and can be filled to most any application.

-Cost of construction is low, as is maintenance, when needed.

-Good substrate for marine organisms.

Disadvantages -Very few when properly applied and well constructed.

- E. Jetties Long linear mounds of piled large stone, constructed perpendicular to the shore usually to stabilize inlets, or provide protection to harbors.
- Aim -Jetties aim to limit longshore transport by projecting into the transport zone and causing the current to drop its sediment load.
- Jetties also aim to protect harbor areas from wave action.
- Application -In New Hampshire, jetties are used at Hampton to stabilize the harbor inlet, and at Rye and Little Harbors to provide protection from waves.
- Disadvantages -Turbidity at the tail end: sediment laden waters wash around the seaward end of the jetty causing deleterious effects on fish, shellfish, and vegetation.
- Pocket Beach Effect: the beach will slant across between the shoreline and the seaward end of the downdrift jetty.
- Energy reflection: waves -- particularly those associated with storms -- and currents are reflected by the jetties and can cause ill effects.
- Minor disadvantages include their blight to the aesthetic nature of many coastal settings, and their hazard to navigational safety.
- F. Groins Short jetties, or linear mounds of piled stone constructed perpendicular to the shore to impede longshore transport.
- Aim -Accretion on beach by trapping sand from longshore transport.
- Reduce the rate of longshore transport. Often groins are used in conjunction with nourishment projects in order to slow down the loss of the artificially-placed fill.
- Application -Groins in New Hampshire are used for each aim listed above and are located at Hampton Beach, North Beach, Hampton, and Wallis Sands Beach, Rye.
- Disadvantages -When groins trap sand from the longshore transport system, they deprive a downstream area of its incoming sediment. The result is the starvation of areas downstream as a consequence of deposition on the up-current side of the groin.
- Turbidity at the tail end, and;
- Energy reflection as stated in E. above.

- G. Beach Nourishment Consists of the direct placement of sand fill on an eroded section of beach.
- Aim -Nourishment attempts to rebuild the beach by artificially replacing sand removed by natural causes.
- Application -Nourishment is a viable alternative for erosion control when the eroding beach is a recreational asset, and the resurrection of the beach will result in increased revenue in the area. In New Hampshire, nourishment has been undertaken at Hampton Beach and Wallis Sands Beach, Rye.
- Disadvantages -Nourishment is only a short term solution to a long-term problem due to the force of Longshore transport (page 16). The currents that transport sediments along the shoreline will continue and carry the newly placed "nourishing" sand in the direction of the downdrift and eventually remove it from the beach.
- Forces causing the original erosion problem still are active, resulting in rapid loss of fill.
- H. Sidecaster Dredge Built on a barge, the sidecaster dredge operated in a manner similar to a snow blower. Sand is picked off the bottom by suction, then thrown to the side through a chute.
- It is used periodically as a short-term solution to channel shoaling.
- It is used for small jobs entailing movement of 5,000 - 15,000 cubic yards of sand.
- Aim -To keep channels clear for navigation.
- Advantages -Simple principle of operation.
- Immediate results.
- Low cost of operation.
- Well suited for work in rough areas.
- Owned by Corps of Engineers (easily available).
- Disadvantages -Short-term solution.
- Pickup and disposal of sand kill marine organisms.
- Limited dispensing range.

I. Transport Dredge

Built on a barge, the transport dredge picks sand off the bottom by suction, and deposits it in the hold of the barge. The barge is then navigated to the dump site and the dredged material is evacuated through trap doors in the bottom of the dredge.

-It is used for small jobs, where the dredged material cannot be deposited near the dredge site.

Aim

-To keep channel clear for navigation.

Advantages

-Simple principal of operation.

-Greater range of disposal than sidecaster dredge.

-Can be used in areas necessitating removal of dredge material.

-Longer term solution than sidecaster because material is removed from the area.

Disadvantages

-Limited volume on each dump.

-Transportation between dredge and dump sites takes some time (as opposed to sidecaster dredge).

-Not good in rough seas.

-Pickup kills marine organisms.

-Can only dump under water.

-Dumping smothers marine organisms.

J. Hydraulic Dredge

Picks up sand off the bottom by suction, then mixes the sand with water and transports the mixture by pipe to the dump site.

-This method is used for large-scale dredging where removal of material from the dredged area is essential.

-This method often dispenses dredged material as artificial beach nourishment as the means of disposal (as at Hampton Beach).

Aim

-To clear channels or mooring areas and deposit material as artificial fill.

Advantages

-Efficient means to remove large volume of sand from an area.

-Practical method to nourish beaches in vicinity of dredge site.

Disadvantages -Dump site limited in distance from dredge site.
-Restricted to well-sheltered areas.
-Marine organisms killed at dump and dredged sites.

FACTORS AFFECTING TOTAL COST OF CONSTRUCTING VARIOUS PROTECTIVE DEVICES

1. Availability of rock (distance to quarry)
2. Transportation of rock from quarry to construction site (rail, truck, barge)
3. Quality of rock
4. Season of year (essential work undertaken during winter is more expensive)
5. Variation in price of sheet steel or precast concrete
6. Characteristics of location
 - bedrock interference
 - types of soil
 - interference to construction by roads, buildings, etc.
 - wave, current conditions
7. Location of suitable borrow site for nourishment
 - onshore -- more expensive plus overland transport
 - offshore -- suitable area more common
 - quality of sediment (suitable for dump site)
8. Conditions at dump site
9. Means of spreading dumped sand
 - bulldozer
 - move hydraulic pipe around
 - natural spreading by waves
10. Supply and demand -- cost of services vary with demand

EXISTING GOVERNMENTAL INFRASTRUCTURE

There are numerous governmental agencies which have jurisdiction in the shoreline area of New Hampshire's coastal zone -- either through ownership or governmental policy. Community-owned lands are scattered throughout the shore area. State and federal agencies not only own portions of New Hampshire's tidal shoreline, they also perform maintenance of such facilities as roads and seawalls.

It is recommended that one person from the State Coastal Program be responsible for coordinating the activities of the various governmental agencies involved with programs dealing with shoreline change and erosion. This person would meet with personnel from such agencies as the Department of Public Works and Highways and the Fish and Game Department to set up an appropriate framework to coordinate activities. They would discuss pending and proposed actions that might affect another agencies programs in the area. They would do other such things to insure proper coordination amongst the pertinent governmental agencies in conformance with the Coastal Zone Management program.

Town Jurisdiction

There is relatively little town-owned property along New Hampshire's tidal shoreline. This property is in the form of town beaches, town landings, or frontage at the end of town-owned access roads. Since most town holdings are scattered throughout areas under other jurisdiction to other agencies on a contractual basis.

For example, the Town of Hampton owns a section of Hampton Beach south of Haverhill Street. The town relies on the Department of Resources and Economic Development (DRED), which allocates funds and monitors (through the Department of Transportation) maintenance and repairs to the seawall. DRED would be responsible for work on the seawall in this town-owned section. At Jenness Beach in Rye, the town owns frontage at the ends of streets. This property is so small that the DRED maintains the cement seawall for the length of the entire beach which is owned by the state.

Along town-owned shorefront property where Route 1A lies immediately landward from the beach, such as at Jenness Beach, Rye, the DOT has inherited jurisdiction by virtue of its interest in maintaining the road. The DOT clears debris

from the road and replaces it on the beach after large storms and maintains the seawall, as previously mentioned.

In town-owned areas which are not bounded by other holdings, the town must provide its own maintenance. Needed repairs could be provided by the town Department of Public Works, contractually by the state DOT or a private construction firm, or, as requested, by the Corp of Engineers.

State Jurisdiction

State-owned and maintained land comprises much of New Hampshire's tidal shoreline. These holdings are divided up amongst three state agencies: The Department of Transportation; the Department of Resources and Economic Development, Division of Parks and Recreation; and the Fish and Game Department.

Most of the state shoreline falls under the control of the Department of Transportation (DOT). The major concern of the DOT along the coast is to protect and maintain State Highway 1A. In those areas where there is so little land between the high water mark and the road that no one owns the property, the DOT assumes direct responsibility for shoreline protection (Oudens, 1978). A partial listing of areas under DOT jurisdiction includes the shoreline from Godfrey's Ledge off North Hampton Beach north to Rye Beach, from Ragged Neck north to Concord Point, and from Seal Rocks to Odiorne's Point State Park (Corps of Engineers, 1960).

In other areas, such as Hampton Beach and North Beach in Hampton, the DOT maintains Route 1A, but not the shoreline, despite the road's proximity to the higher water mark (Oudens, 1978). Along this stretch, the shoreline is maintained by the Division of Parks and Recreation because it is part of Hampton Beach State Park. However, the DOT does clear storm deposited debris from the highway and returns it to the beach.

Where Route 1A crosses bodies of water, as at the Hampton Harbor inlet, the DOT maintains the bridge and pilings. At the inlet, the DOT conducts continual monitoring of channel depth in order to keep abreast of possible undermining of the bridge supports. Scouring has necessitated repair work in the past which has entailed placing armor stones around the base of the pilings (Oudens, 1978).

Within the Great Bay estuary, the DOT maintains the Hilton Park Rest Area on Dover Point. They acquired jurisdiction of this park from the Department of Resources and Economic Development, Division of Parks and Recreation (DP&R) when the Spaulding Turnpike was constructed (Sullivan, 1978). Due to the high velocity tidal currents which flow through Dover Point Strait, the DOT monitors the depth of the channel in order to protect the bridge pilings. In response to these high velocity currents, the DOT maintains a revetment around the point.

The state parks along the coast of New Hampshire are maintained by the DP&R. There are five state parks on the coast: Hampton Beach State Park, Rye Harbor State Park, Wallis Sands State Park (Rye), Odiorne's Point State Park (Rye), and Fort Constitution (Newcastle).

The jurisdiction at Hampton Beach State Park is rather confusing. As previously mentioned, the DOT maintains Route 1A behind the beach and removes storm deposited debris from the road and places it back on the beach. Other than this, the DP&R holds jurisdiction over the beach from the high water mark through the seawall or bulkhead.

However, the DP&R does not maintain the seawall and bulkhead structures. Maintenance of these structures is performed by private construction firms on a contractual basis. These firms are contracted by the DOT upon request of the DP&R, and are paid by the DP&R (Sullivan, 1978).

The beach nourishment projects which were undertaken in 1955, 1965, and 1973 at the north end of Hampton Beach were conducted by the Corps of Engineers. The material for the nourishment was dredged from Hampton Harbor inside the Route 1A bridge. Besides this contract, the state and the Corps also have a contractual agreement pertaining to the Hampton Harbor Inlet. By the terms of this contract, the Corps maintains a channel east from the Route 1A bridge and the state maintains 22 acres of mooring space in the harbor (Sullivan, 1978).

At Rye Harbor State Park on Ragged Neck, the DP&R maintains the natural boulder revetment around the point. Normal maintenance consists of placing the rocks back on the shore when displaced landward by storm waves. Within the harbor, the DP&R maintains the state-owned shore front. This includes the commercial pier and the revetment behind the pier. The DP&R inherited jurisdiction over this parcel of land from the DOT in 1962 when the harbor was dredged and the

pier was built. Prior to that time, the DOT had maintained the harbor since there was ownership seaward of Route 1A.

At Wallis Sands State Park the DP&R is responsible for maintenance of the small seawall as well as the parking lot and bath house. The beach is wide at the park and affords the structures ample protection.

To help maintain the sand beach, the Corps of Engineers nourished the beach in 1973 with material dredged from Hampton Harbor. This nourishment was part of the contract between the state and the Corps which covered the 1973 dredging of Hampton Harbor and nourishment of Hampton Beach.

Odiorne's Point State Park stretches from Odiorne's Point north to Frost Point. The shore is predominantly bedrock in this region and requires little or no maintenance. One exception is at the north of Odiorne's Point where erosion of glacial material was stabilized by revetment in the early 1970's. The jetty at Frost Point sustained heavy damage during the February 1972 storm. The jetty was repaired by the Corps of Engineers later that year.

State jurisdiction of shoreline within the Great Bay Estuary is limited to the holdings of the Fish and Game Department (F&GD), with the exception of Hilton Park on Dove Point which is maintained by the DPW&H and any stretch of shoreline so near a state highway that there is no ownership between water and road. One F&GD holding is the Bellamy River Access in Dover. This 17-acre area is near Hilton Park on Dover Point. In Greenland, the F&GD owns 18 acres along the Winnicut River. In Durham, they own the Adams Point State Wildlife Area which consists of 80 acres, 1000 feet of marshy shore, and 4000 feet of rocky shore. The remaining F&GD tidal frontage is the 272-acre Hampton Saltmarsh Conservation Area which is not located in the Great Bay Area, but in Hampton (N.H. Fish & Game Department) and Chapman's Landing at the mouth of the Squamscott in Stratham.

Private Jurisdiction

That shoreline which abuts private land falls under the jurisdiction of the property owner, although the owner does not legally own land seaward of the high water mark. Any protection of shorefront property must come from the property owner. The owner can move to protect his holdings, while the neighboring owners may also construct their own protection. In this case, the result usually

is piece meal protection of areas which warrant continuous protection. The alternative solution is for property owners to band together and build such a continuous device. Any construction must comply with town, state and federal regulations.

Federal Jurisdiction

Direct federal jurisdiction is limited in New Hampshire due to the limited federal property. Fort Stark in Newcastle, held by the U.S. Navy; part of Fort Constitution in Newcastle, owned by U.S. Coast Guard; and Pease Air Force Base in Newington are the three operating federal holdings with salt water frontage. They are responsible for any protection needed along their shores.

Indirect federal jurisdiction of various areas lies with the Corps of Engineers which is a division of the Department of the Army. The Corps owns no property in New Hampshire, but does hold contracts for various projects, such as channel dredging at Hampton Harbor, beach nourishment at Hampton Beach and Wallis Sands State Parks and maintenance of storm damaged protective devices, for example, the Frost Point (Rye) jetty.

The Corps of Engineers can be asked to survey areas experiencing severe erosion. Congressmen from the state, at the request of local interests, seek the committees on Public Works of both the House and Senate to resolve that the Corps conduct a survey of regions experiencing severe erosion (Corps of Engineers, 1977).

THE ROLE OF THE FEDERAL FLOOD INSURANCE PROGRAM

The Flood Insurance Program would not directly impinge upon the control of shoreline change in New Hampshire's coastal area. The administering agency, Federal Emergency Management Agency, is more concerned with regulating the types of development that might occur in such areas. This agency seeks to reduce losses due to floods by regulating building location and elevation, rather than get involved with structural or nonstructural alternatives for protecting the shoreline against erosion.

Indirectly, such an activity could be considered a control alternative, since it ultimately may prevent aggravated problems of erosion. Homes and other deve-

lopment will not be allowed to contribute to coastal erosion simply because construction would be discouraged in such areas.

MECHANISMS FOR CONTINUED MONITORING OF TIDAL SHORELINE CHANGE

Two sets of recommendations for monitoring New Hampshire's tidal shoreline changes are made. The first assumes (and recommends) a total budget for the process of something less than \$20,000 a year and most probably \$10,000 a year. The second set assumes a budget of about \$100,000 a year.

Low Budget

The state should have aerial photographs of the tidal shoreline taken annually, preferably on or about the 31st of July at a low tide.

These photographs ought to be done by professional aerial photographers and enlarged to a scale of 400' to the inch. Comparison of these annual photographs will most easily document shoreline changes taking place from year to year. Areas identified as being subject to significant shoreline change ought to be monitored by visits by Coastal Management staff. These areas are:

- Seabrook Beach and Dunes
- Hampton Harbor Inlet
- Hampton Beach (North End)
- North Beach (Hampton)
- Little River Saltmarsh
- Bass Beach Saltmarsh
- Straw's Point
- Varrell's Point
- Rye Harbor - North Shore
- Foss Beach, Rye
- Parson's Creek Saltmarsh

Contact should be maintained with the Wetlands Board, the Water Resources Board, the N.H. Port Authority and the Corps of Engineers so that any man-made alteration of the shoreline can be visually and photographically monitored to determine its effect, if any, on the erosion of nearby shoreline.

Coastal Program staff should keep up to date on Corps of Engineers policies toward shorefront protection and should play an active role in assisting Corps studies.

High Budget

In addition to the items listed in the preceeding Low Budget section, given a budget of \$100,000 a year or so, the Coastal Program effort could play a significant role in seeing that measures are taken to correct erosion problems.

For example, at North Beach in Hampton, it is clear that the erosion problem must be dealt with, but a combination of limited financial resources (neither private property owners, nor the town have funds), limited jurisdiction (state and Corps of Engineers do not have all necessary powers), and different philosophies about what has to be done (private property owners and local politicians disagree) have resulted in no action at all -- except for continued erosion and damage. Coastal Program staff could play an active role getting the parties pulled together to agree on a plan of action that would be fundable and acceptable to all groups. The history of this problem would indicate that a year's worth of meetings and some detailed engineering work would be required, utilizing previous Corps studies, the NHDOT records, and the comments of local officials and local citizens on each.

Dredge and fill projects along the shore ought to be fully investigated by the Coastal Program staff prior to any action being undertaken. Investigating should include bottom profiles at various places which conceivably could be significantly affected by the proposed project. Coastal Program staff ought to then review any such proposal recommend design features to minimize harmful effects after construction is completed. Coastal Program staff ought to monitor the area periodically for two years or until shoreline conditions have stabilized.

The entire shoreline ought to have base profiles surveyed periodically (at 5 year intervals) in the same places surveyed by previous Corps of Engineers efforts. (See Corps of Engineers, Shore of the State of New Hampshire, Beach Erosion Control Study, May 21, 1962.)

This would provide a long time series record of coastal change and would aid in predicting future problems.

Finally, it is possible that the Seabrook Nuclear Power Plant, once operational, will have an input on seashore currents and therefore on erosion and sedimentation. No predictions have been made on these effects to date. Attributing any such changes to the operation of the power plant will be a difficult proposition at best given the inherent variability of ocean currents in the area.

Nonetheless, prior to operation, bottom profiles ought to be gathered and once operation has begun, ought to be resurveyed periodically.

ANNUAL REPORT

Under either scale activity a report ought to be made annually indicating what changes have taken place since this report, what induced those changes insofar as it can be inferred, and what recommendations are currently being made. The report should be circulated to all concerned state offices and communities. In addition to reports, implementation should address the findings and recommendations of said reports.

FUNDING FOR SHOREFRONT EROSION CONTROL

Federal:

The Corps of Engineers is the Federal Agency responsible for handling the Federal interest in beach erosion prevention and repair. The legislation which deals with this problem says that it is "the policy of the United States to assist in the construction, but not maintenance, of works for the improvement and protection against erosion by waves and currents of the shores of the United States, its territories and possessions."

Three classes of eroded shorelines are eligible for varying levels of Federal assistance. These are: 1) publically owned shoreline, 2) shoreline eroded as a result of navigation improvements placed by the Federal government and, 3) certain privately owned shorelands, where a public benefit can be shown.

Before Federal money can be used in these projects, it must be shown, through a planning study, that the public benefit will outweigh the public cost.

The Corps funds projects in two basic ways. The first is called the small project program. In this program the Corps may spend up to \$1 million for construction. These projects may be used to repair eroded public lands or to mitigate for Federal navigation works. These projects are assigned at the discretion of the Secretary of the Army, and paid for out of the Corps public works budget. In the regular program the funds must be specifically appropriated by Congress before the project starts.

In either case the initiation of the project must come from local agencies or citizens concerned about erosion. After local initiation, the corps will study the project area, consider the cost/benefit ratio and recommend for or against the project. If the recommendation is for, then the project will be done if the Secretary of the Army or the Congress (depending upon the project size) funds it. Failing action by the Federal Government, the State or local government units or individual property owners will have to fund any improvements that are made.

State:

In order for the state to fund any erosion control work, it will be necessary for the legislature to authorize and fund the project and for the Governor and the Executive Council to approve the contracts for specific work. This holds true for projects funded entirely by state funds or funded partially with federal funds. The sources for the state funds would be the general revenues of the State of New Hampshire or from an acceptable application for Community Development funds made by the state. In this case the money would come from federal sources but would be administered as if it were state funds.

Local Units of Government:

If local units of government decided to pay for beach erosion improvements, funding would come from local property taxes. The method and timing of using the tax money can vary. The town can elect to pay the entire cost in one year and raise the tax rate enough to do this. The town can vote to put a small amount into a beach erosion fund which will be spent when there is enough money available to do all or some of the project, or the town can elect to borrow the money to do the work now, and pay off the loan over time, raising the tax rate somewhat to pay the annual cost.

If either the state, county or local unit of government elects to conduct and pay for a shoreline erosion abatement project, they will have to receive a permit from the Corps of Engineers, for the work they wish to do. They may also have to satisfy the requirements of the State of New Hampshire Wetlands Board.

There appear to be no other sources of funds for this kind of project.

PERSONS INTERVIEWED

John Hays, NHDOT, Division IV, Durham, N.H.

Frank Richardson, N.H. Wetlands Board, Coastal Office

Dr. Henry Mathieson, UNH Jackson Estuarine Lab

Dr. Fred Short, UNH Jackson Estuarine Lab

Frank Shaugnessy, Master's Candidate, UNH Jackson Estuarine Lab

Mark Otis, Navigation Division, U.S. Army Corps of Engineers

Dr. Robert Croker, UNH Zoology Department

Tom Ballestero, Civil Engineering Department, Water Resource Research Center,
UNH

George Hardardt, Hampton Public Works Director

Bob Southworth, Normandeau Associates, Bedford, N.H.

Richard Antonia, Director N.H. DRED

Bob Dowst, NHDOT

Henry McCrone, NHDOT

Thomas Currier, NHDOT

Malcolm Chase, Kimball Chase, Portsmouth, N.H.

Ken Fink, UNH Marine Seagrass Program

Marjorie Swope, N.H. Conservation

George Smith, N.H. Port Authority, Portsmouth

Jack Kaffrey, Emergency Division, U.S. Army Corps of Engineers

Tom Brouha, U.S. Army Corps of Engineers

Bruce Hoveland, Society for the Protection of N.H. Forests

Sarah Thorn, Society for the Protection of N.H. Forests

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